END
DATE
FILMED
5-80
DTIC

Technical Note 3-80

USE OF ROUGH TERRAIN FORKLIFTS FOR NIGHT AMMUNITION

TRANSFER TASKS

Bernard M. Davall

February 1980
AMCMS Code 612716.H700011

U. S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

80 4 . 11 031

Destroy this report when no longer needed.
Do not return it to the originator.

The findings in this report are not to be construed as an official Department
of the Army position unless so designated by other authorized documents.

Use of trade names in this report does not constitute an official endorsement
or approval of the use of such commercial products.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Note 3-80	**2. GOVT ACCESSION NO.**	**3. RECIPIENT'S CATALOG NUMBER**
4. TITLE (and Subtitle) USE OF ROUGH TERRAIN FORKLIFTS FOR NIGHT AMMUNITION TRANSFER TASKS		**5. TYPE OF REPORT & PERIOD COVERED** Final report **6. PERFORMING ORG. REPORT NUMBER**
7. AUTHOR(s) Bernard M. Davall		**8. CONTRACT OR GRANT NUMBER(s)** DAAK11-79-C-0046
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Human Engineering Laboratory Aberdeen Proving Ground, MD 21005		**10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS** AMCMS Code 612716.H700011
11. CONTROLLING OFFICE NAME AND ADDRESS		**12. REPORT DATE** Feb 80 **13. NUMBER OF PAGES** 62
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) HEL-TN-3-80		**15. SECURITY CLASS. (of this report)** UNCLASSIFIED **15a. DECLASSIFICATION/DOWNGRADING SCHEDULE**

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ammunition	Ammunition Supply Point
Material Handling Equipment	Night Operation
Forklifts	Night Logistical Operations
Rough Terrain Forklifts	
Aerial Detection	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the testing efforts to prove a constrained, soft white light concept for use on rough terrin forklifts performing night ammunition transfer task in the forward battle area.

DD FORM **1473** EDITION OF 1 NOV 65 IS OBSOLETE

USE OF ROUGH TERRAIN FORKLIFTS FOR NIGHT AMMUNITION
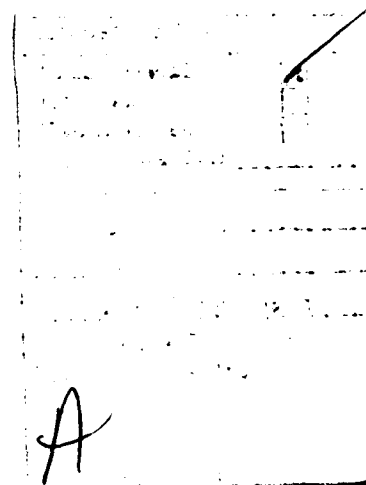
TRANSFER TASKS

Bernard M. Davall

February 1980

APPROVED:
JOHN D. WEISZ
Director
U.S. Army Human Engineering Laboratory

U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland   21005

1

PREFACE

The results reported in this document are based on the efforts expended by the remaining members of the HELFAST Team who spent many nights conducting the tests and gathering the date. They are:

Don Mackey
Wendell P. Holman
CW3 William Iiams
SP5 Barry Winters

CONTENTS

FIGURES

TABLES

USE OF ROUGH TERRAIN FORKLIFTS FOR NIGHT AMMUNITION

TRANSFER TASKS

SECTION I

GENERAL

BACKGROUND

In the Fall of 1977, as a result of a recommendation by the US Army's Ammunition Initiatives Task Force (AITF), the US Army Human Engineering Laboratory established a small team (originally named HELLOG but now called HELFAST) to investigate Human Factors problems associated with the Ammunition Logistical System. After some preliminary research and a brief literature review, this team selected the human performance of Material Handling Equipment (MHE) Operators in a Corps Ammunition Supply Point (ASP) for the initial area of study.

The initial effort was to develop a set of questionnaires (one for experienced operators and one for inexperienced [AIT level] operators) to query the soldier in the field about the problems with the current inventory of MHE. The most startling fact that came from this survey was that none of the inexperienced (recent AIT graduates in MOS's 55B, 76V, and 62F) and less than 60% of the experienced operators had ever used MHE at night.

In June 1978 the HELFAST team visited Ft. Hood, Texas, to observe the Ammunition Transfer Point (ATP) test conducted by TRADOC Combined Arms Test Activity (TCATA). This was a five-day field test run both day and night. At night, red acetate was taped over the head and floodlights on the 6,000-lb Rough Terrain Forklifts (RTFL) used in the ATP. Their test report stated that at night with the red acetate filters:

    1. The forklifts were still "highly visible from the air."

    2. "There was a 40% decrement in tons of ammunition moved per hour." (Conversely, it took 40% longer at night to perform the same ammunition transfer tasks.)

In November 1978 the HELFAST team opened a Logistics Testing Facility (LTF) at Aberdeen Proving Ground, Maryland. The purpose of the LTF was to establish operator performance levels by conducting tests of the ammunition transfer tasks required in Corps ASP using the current inventory of MHE and a large sample of subject operators. From the beginning, night testing was included. About 25% of the first 1,000 tests conducted at the LTF were at night.

This report describes the night testing and the results achieved.

LIGHTING SYSTEMS

The 6,000- and 10,000-lb Rough Forklifts (RTFL) have two sets of night lights available when issued. These are:

    1. The service drive headlights with a floodlight mounted front and rear (see Figure 1).

    2. Blackout drive and marker (Figure 1).

    One might characterize these systems as "too much" and "not enough."

In November 1978 the HELFAST team developed three alternative systems which, by wiring two of these systems in both series and parallel, added five additional options of night lighting to the two basic systems.

The HELFAST options were:

    1. Two small 24-volt handheld auxiliary lights normally found in the cockpit of Army aircraft were mounted inside the top outer corners of the frame behind the forks on the RTFL's (see Figures 2 and 3). These lights were adjusted to point at the front half of the forks. They could be adjusted for either red or white light and either wide or narrow beam.

    2. Four 24-volt track vehicle headlights were mounted on the four corners of the overhead protection guard. These pointed down and out at 45° (see Figure 2). These lights were wired in series and in parallel (in pairs) so that 12 or 24 volts (low and full power) options were available.

    3. Four more track vehicle headlights were mounted in the center of each side of the overhead protection guard (see Figure 2). These were also pointed out and down at 45° and were shielded by taping an 8-inch section of heavy cardboard tubing to each light (see Figure 1). These lights were also wired with a low and full power option.

    4. A small control box for selecting the alternative system was mounted on the left side of the RTFL next to the driver's seat (see Figure 4).

    5. The total number of options could be doubled by using red filters on any of the five systems described above, as well as on the head and floodlights issued with the vehicle and used in the TCATA tests.

THE THREAT

Normally, the Corps Ammunition Supply Point is located near the Division rear boundary; anywhere from 40-60 kilometers to the rear of the forward edge of the battle area (FEBA). It may or may not be behind the light line. The Ammunition Transfer Point (ATP) would be in the Brigade rear area, usually less than 20 km from the FEBA, and forward of the light line. The primary threat to either area is from enemy aircraft most likely

FLOODLIGHT

BLACKOUT DRIVE LIGHT

HEADLIGHT

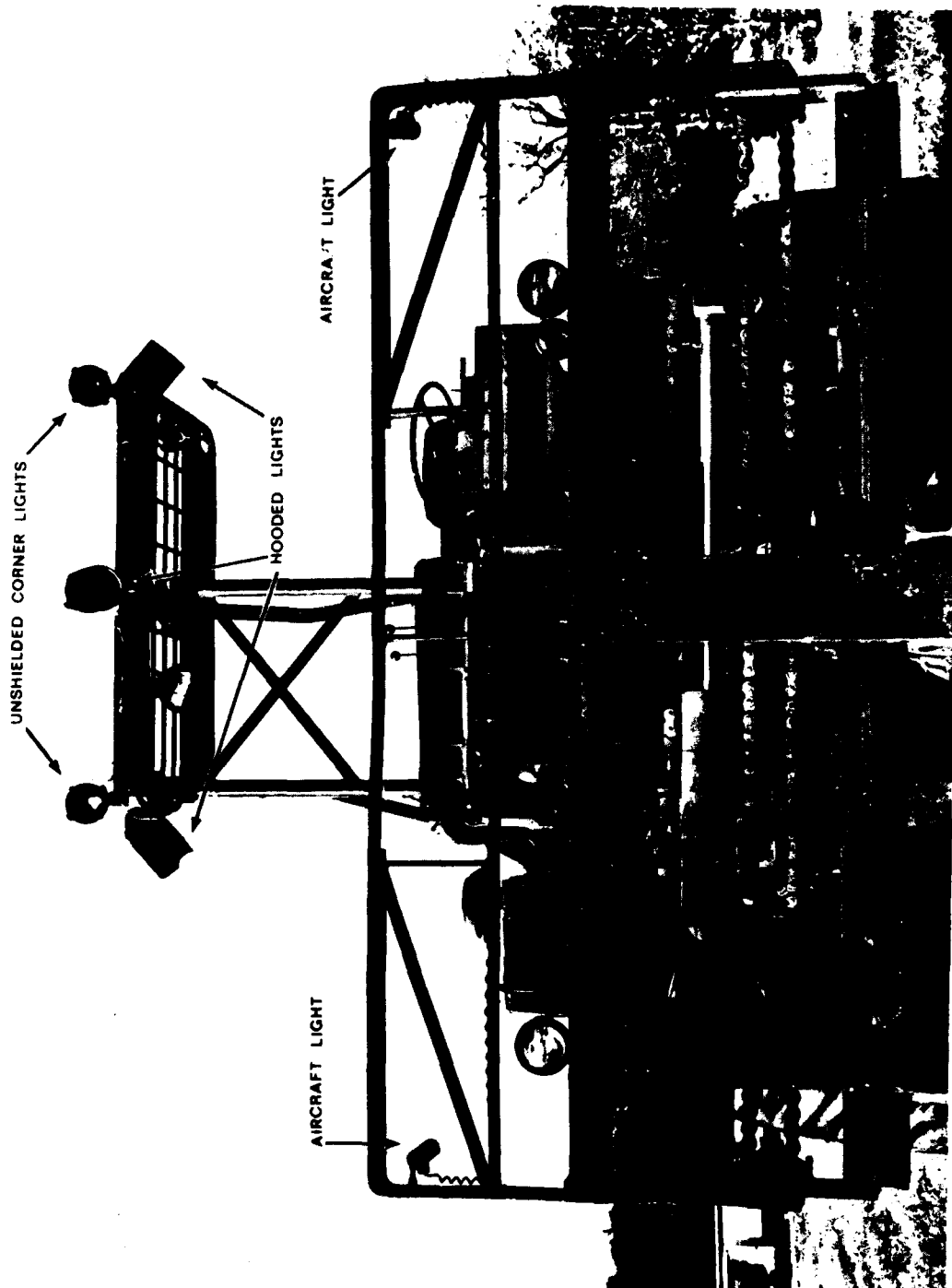Figure 1. Standard lighting system available on 6,000- and 10,000-lb rough terrain forklifts.

Figure 2. Additional lighting systems added by the HELFAST Team.

AIRCRAFT LIGHT

Figure 3. Aircraft lights mounted on the forklift frame.

9

Figure 4. Control box for alternative lighting systems.

high performance fixed wing aircraft. These aircraft may have additional target detection sensing devices (such as infrared) to augment the pilot's visual detection capability. However, the effort reported in this report is aimed only at reducing the signature that is visually detectable by the pilot at night.

Although forklifts operating in a Corps ASP may be behind the light line, they present a very unusual and distinctive visual signature if they are using the standard head and floodlights as they have three bright lights forming a triangle in the front and one lone floodlight in the rear. Since an ASP could have 10-15 of these vehicles operating in a small area, and since ASP's are prime targets of opportunity for enemy aircraft, the distinctive signature the current equipment offers is very undesirable.

The ammunition transfer point, being much closer to the FEBA, is subject to attack from aircraft as well as artillery if its location is fixed. Therefore, the probability of visual detection from the air must be minimized. With the current lighting systems available on the RTFL, the MHE operators in the ATP truly have to choose between "too much" and "not enough."

NIGHT AMMUNITION RESUPPLY OPERATIONS

There are no valid estimates of the percent of the demand on either an ASP or ATP that will be made during hours of darkness. One approach is to assume that the demand is uniformaly distributed during a 24-hour period, and, since, on the average, it is dark almost half the time, half the demand is at night. Perhaps a more sensible approach would be to say that units will send convoys in the early to mid-morning to replenish what was used during the previous night, and again during evening to replenish what was used during the day. In either event, we will still expect about half the demand to be made at night.

Perhaps a more thoughtful analysis of the second situation presented above may follow this line of reasoning. Since we cannot assume air superiority, and since ammunition convoys are slow, ponderous and also prime candidates for air interdiction missions, many ASP customer units may choose to do most of their ammunition resupply at night to help protect their convoys.

Whatever line of reasoning one chooses, it is difficult to define a realistic scenario in which more than half of the ammunition resupply is not done at night.

As mentioned earlier, a survey completed by the HELFAST team revealed that less than 60% of the experienced MHE operators had ever used their equipment at night and that none of the new operators receiving AIT level MHE operators' training get any night training.

Thus we have a situation in which, under a realistic tactical scenario, many units will want to be resupplied with ammunition at night,

11

yet many of our operators have never used MHE at night. If it is used at
night with the headlights and floodlights, it presents a unique and
distinctive visual signature to enemy pilots pinpointing the location of a
high priority ground target. If the MHE operators attempt to use blackout
drive and markers (the "not enough" system), the time required is prohibi-
tive and the resupply mission cannot be accomplished.

OBJECTIVE OF TEST

To develop an alternative night lighting concept that will allow MHE
operators to perform their mission while significantly reducing the visual
signature provided by the currently available headlights and floodlights
(the "too much" system) when viewed from the air.

SECTION II

TESTING

THE LOGISTICS TESTING FACILITY OPERATIONS

The HELFAST Logistic Testing Facility is a 20-acre tract located adjacent to the Edgewood Area of Aberdeen Proving Ground. It has open fields with undulating terrain and moderate vegetation (see Figures 5, 6, and 7). However, it is surrounded by high, well established trees that provide very adequate shielding from ambient light sources.

The equipment currently on hand includes:

1. 2 each 6,000-lb Rough Terrain Forklifts.

2. 1 each 10,000-lb Rough Terrain Forklift.

3. 1 each 5-ton Hanson crane.

4. 1 each M-127A1 12-ton C&P trailer.

5. 1 each M-813 5-ton truck.

6. 1 each M-520 GOER 8-ton truck.

7. 1 each M-548 6-ton tracked cargo vehicle.

8. 2 each 8' x 8' x 20' milvans.

9. Inert pallets of:

    a. 105mm tank ammunition.

    b. 155mm propelling charges.

    c. 155mm projectiles.

    d. 8-inch propelling charges.

    e. 8-inch projectiles.

Repetitions of the same test can be repeated by the same operator or by different operators under the same conditions (marginal changes in weather being the only uncontrolled variable).

A test is one operator, using one specific piece of MHE, either loading or unloading one type of ammunition from a vehicle. For example:

Figure 5. The HELFAST Logistics Testing Facility, ground view.

HELFAST TEST SITE

1 IN = 200 FT
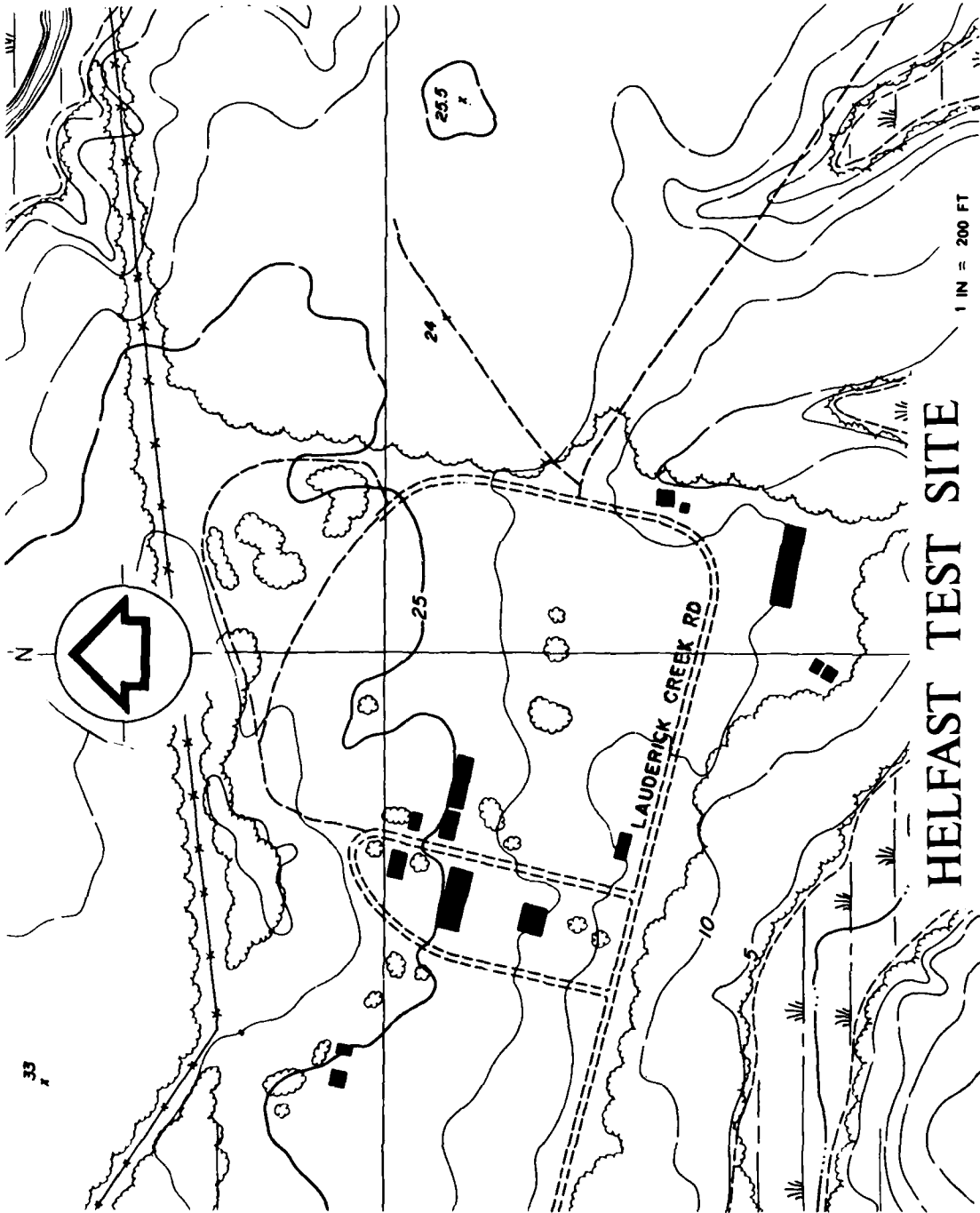
Figure 6. Map of Logistics Testing Facility.

Figure 7. The HELFAST Logistics Testing Facility, showing relationship of a load of 155mm projectiles to a GOER.

1. Load 20 pallets of 155mm projectiles on the GOER with the 6,000-lb RTFL.

2. Unload 5 pallets of 155mm propelling charges from the GOER with the 6,000-lb RTFL.

3. Load 5 pallets of 105mm tank ammunition on the 5-ton truck (with dropsides down) with the 10,000-lb RTFL.

In the bookeeping vocabulary established to keep track of all of the HELFAST data, the terms "cycles," "phases" and "iterations" are used to define specific tests.

1. A "cycle" defines one type of MHE, one load of ammunition and one type vehicle that is being either loaded or unloaded.

2. A "phase" defines the specific activity associated with that cycle such that:

a. Phase I is unloading from a vehicle (i.e., GOER, 5-ton, S&P) to the ground.

b. Phase 2 is loading from the ground to the vehicle.

c. Phase 3 is also loading but is limited to specific selected cases.

d. Phase 4 is cross loading from the S&P to a customer vehicle (i.e., 5-ton, GOER or M-548).

3. The "iteration" is the count of the total number of times that particular "cycle" and "phase" have been repeated. The iteration count continues regardless of the test conditions; i.e., changing operator, day testing, or night testing with a specific night lighting system.

PRELIMINARY TESTING

In addition to the RTFL's two lighting systems, the HELFAST team added five more options; and red filters could be used with six of these seven options (red filters could not be used with blackout drive and markers). Therefore, some preliminary testing had to be conducted to eliminate some of the 13 candidates.

The first criteria to be met was, "Did the candidate lighting system provide adequate light so that the time required to perform the task did not exceed the subject's daylight performance time by more than 10%."

(NOTE: The 10% figure was an arbitrary figure
selected to eliminate lighting systems
that caused night test performances which
were not significantly better than the
40% degradation found in the TCATA test.)

The first trials used the red acetate on the head and floodlights, as had been done at Ft. Hood. Consistant with their results, times in two different tests exceeded the daylight times by 12% and 44%. Based on their reported result of the red filtered lights "being highly visible from the air," the decision was made to concentrate on white light with the remaining systems. Each of these systems provided less light (whether filtered or white) than the head and floodlights, and since the red filters were inadequate with the brightest system, they would be more inadequate with systems that provided less light.

The next series of tests were not performance oriented, but were concerned with visual acuity. Two sets of "Landolt C's" were used (see Figure 8). Each set had two "C's", one that was white on a black background (high contrast) and one that was olive drab (OD) on a black background (low contrast). One set of "C's" were directly in front of the subject and one set was on the left at a 45° angle to the subject's line of movement (see Figure 9). The subject operated a 10,000-lb RTFL on a straight and level stretch of road driving toward "C's". When the subject could correctly identify the direction of the opening in the "C", he would stop the forklift and the distance would be recorded. The directions of the openings were changed after each trial. Five lighting systems were used and each subject made three trials with each lighting system, starting with the dimmest system (blackout drive and marker) and working up to the brightest system (service drive headlights and floodlights). A total of 13 subjects were used.

Figure 10 summarizes the results. Systems A and B were eliminated from further testing as the test results showed them to be totally inadequate. System E (head and floodlights) was kept since it is the current standard item and proved to be the best system in the acuity test. Finally, system C was selected over system D, even though D is consistantly slightly better than C in the acuity test. However, the visual signature of system C was judged to be significantly less than system D (see Figures 11 and 12), and this reduction outweighed the slight improvement in recognition ranges measured in the acuity tests. (This judgement was later verified by photometer measurements.)

Thereafter, all operational testing was done using system C (overhead, center shielded lights, low power referred to as "NO4" on HELFAST data printouts and summaries) and system E (service drive head and floodlights referred to as "NO2" on HELFAST data printouts and summaries). Additionally, all further night testing was performance oriented, and times were compared to the times required to perform the same task during daylight.

OPERATIONAL TESTING

Three cycles were selected for detailed night testing. For each of these cycles, both the loading and unloading phases were tested. For each cycle-phase combination used, both the standard head and floodlights system (system "E" in the night visual acuity tests and "NO2" on the data summaries and computer printouts) and the center hooded lights on low power
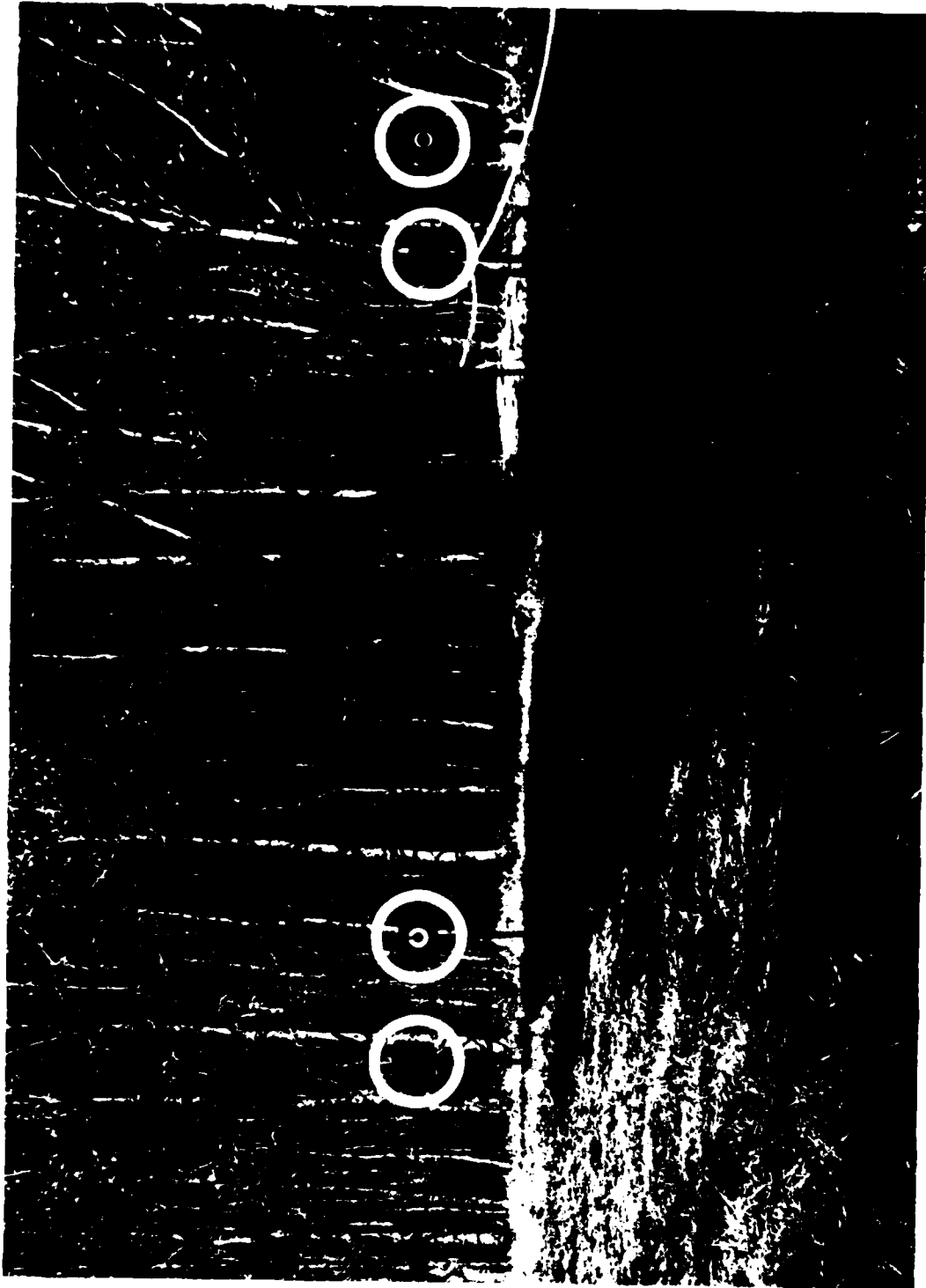
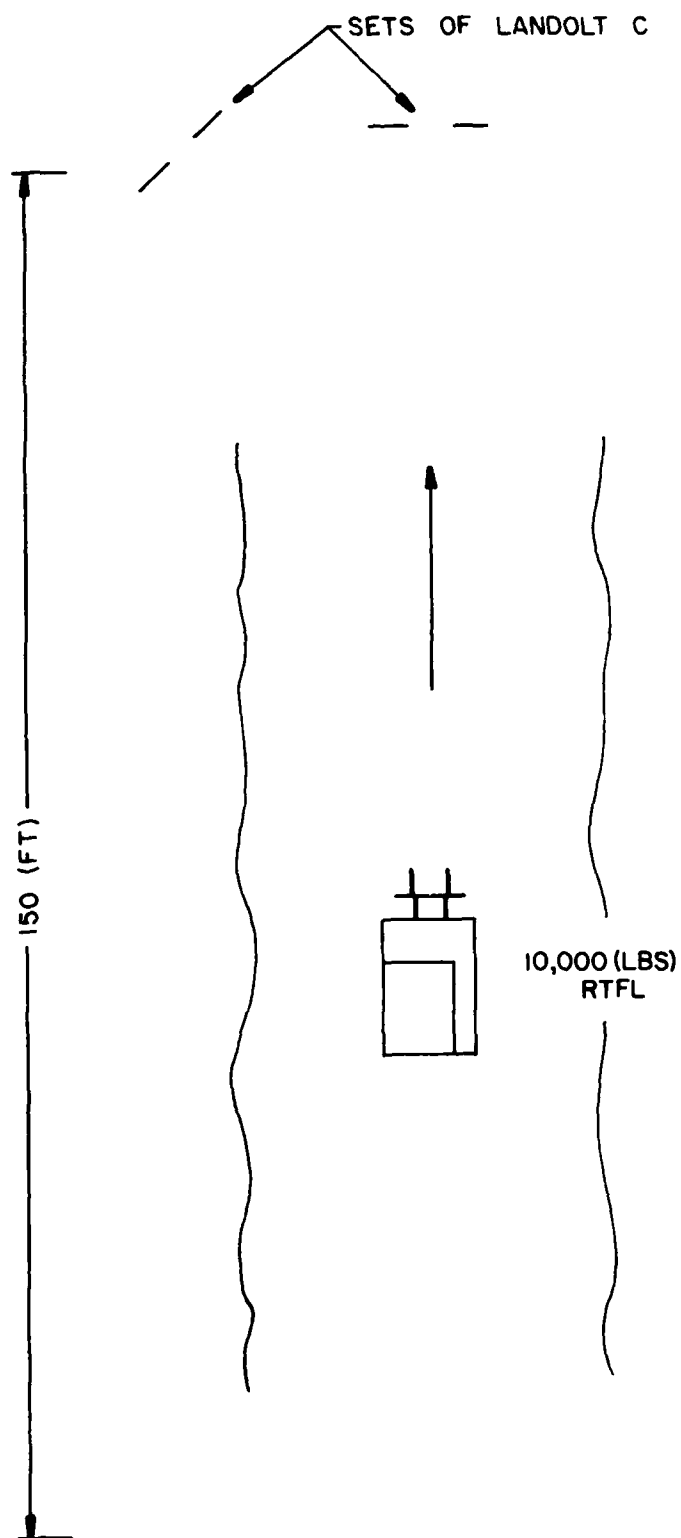Figure 8. "Landolt C's" used in night visual acuity testing.

SETS OF LANDOLT C

150 (FT)

10,000 (LBS)
RTFL

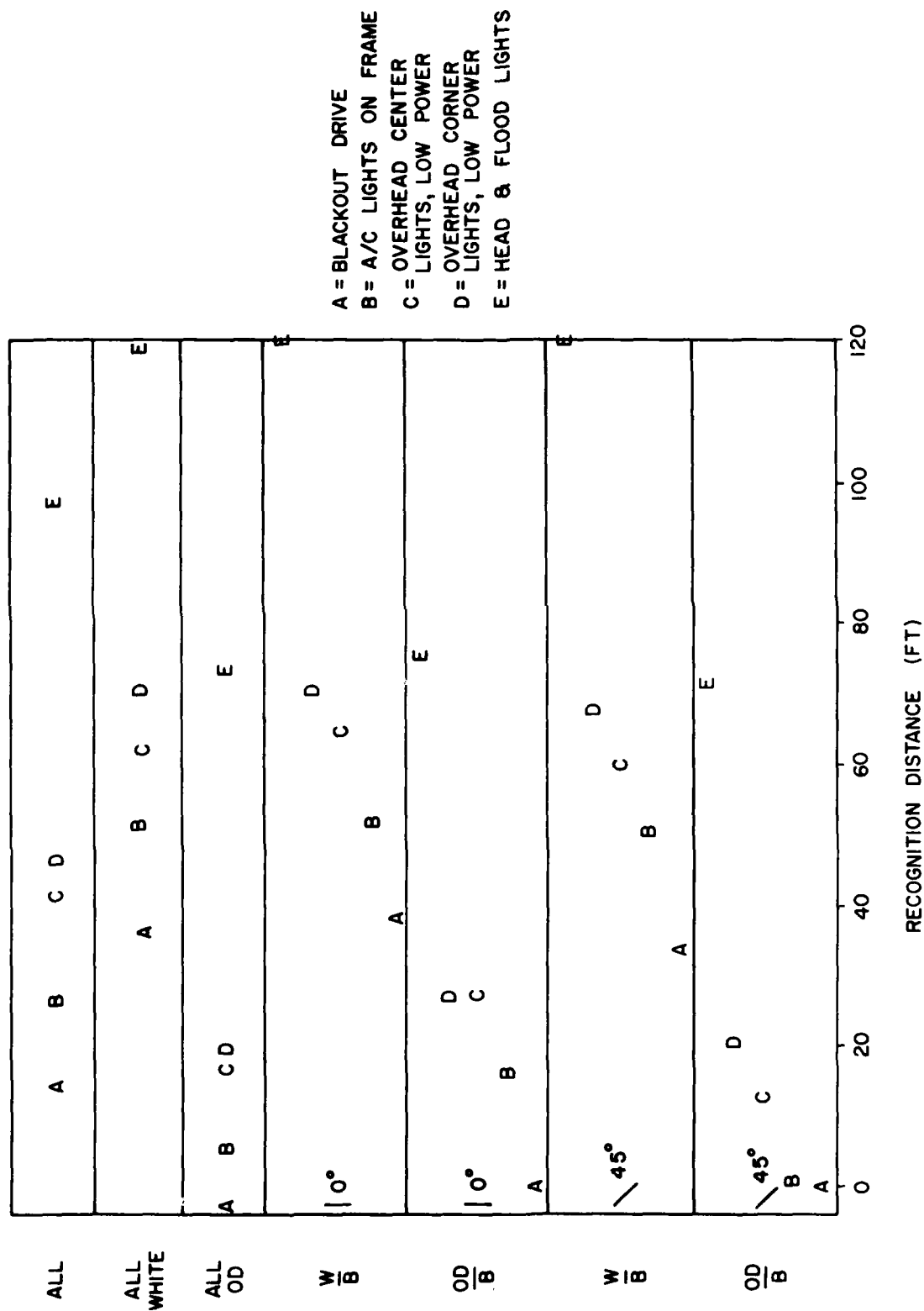Figure 9. Night visual acuity test course layout.

Figure 10. Results for the five systems used in the night visual acuity testing.

21

Figure 11. Night visual signature of lighting system C (center hooded lights, low power).
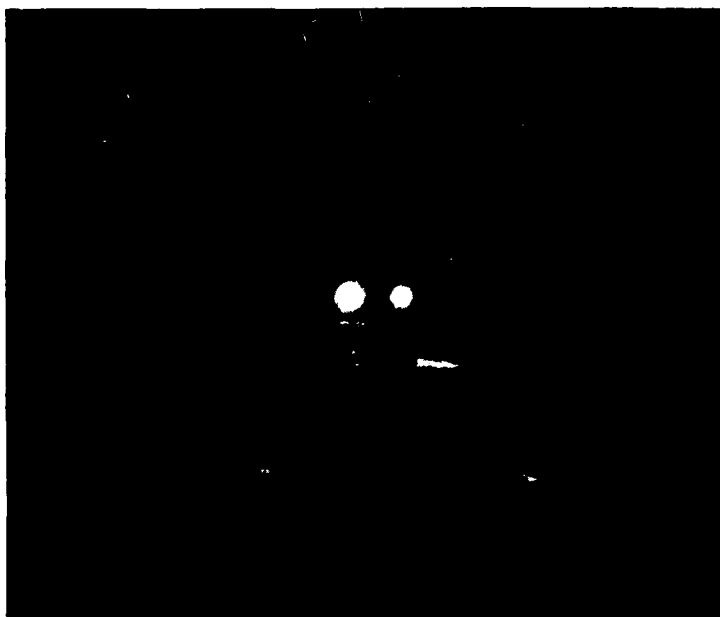

Figure 12. Night visual signature of lighting system D (unshielded corner lights, high power).

(system "C" in the night visual acuity tests and "NO4" on the data summaries and computer printouts) were tested. These results were compared to the results achieved for the same cycle-phase combinations during daylight (except cycle 32-2).

Cycle-phase tested:

1. 14-1: Unload 20 pallets of 155mm projectiles from the GOER with the 6,000-lb RTFL. (Note: The 6,000-lb RTFL can pick up three pallets of 155mm projectiles in one lift. Thus, 20 pallets equals six lifts of three pallets and one lift of two pallets for a total of seven lifts.)

2. 14-2: Load 20 pallets of 155mm projectiles on the GOER with the 6,000-lb RTFL.

3. 19-1: Unload five pallets of 155mm propelling charges from the GOER with the 6,000-lb RTFL. (Note: The GOER can carry a total of six pallets, four in the front section and two in the back section. However, it is very difficult to unload six pallets since the pallet that is in the back, and fartherest from the rear door, cannot be reached by a forklift. To unload it, either a crane must be used to lift it out, or a strap must be used to drag it backward to the rear door. Since this procedure was time consuming and did not measure operator performance, only five pallets were used in loading and unloading 155mm propelling charges on the GOER.)

4. 19-2: Load five pallets of 155mm propelling charges on the GOER with the 6,000-lb RTFL.

5. 32-1: Unload five pallets of 105mm tank ammunition from the M-813 five-ton truck, with the dropsides down, with the 10,000-lb RTFL.

6. 32-2: Load five pallets of 105mm tank ammunition on the M-813 five-ton truck, with the dropsides down, with the 10,000-lb RTFL. (Note: ONLY night test data included.)

DATA SELECTION

In any test of the size and magnitude of the HELFAST Project, some discretion must be used in selecting the data presented. This is not to imply that there is carte blanche to display only that data that proves a preconceived notion. Rather, there is an obligation to ensure that the data presented is cogent for the purposes for which it is presented.

Day Data

Since all of the subjects used in developing the data for this report were recent AIT graduates whose training on MHE was both varied and minimal, the "learning curve" phenomenon was a constant problem. All of these subjects were involved with the HELFAST Project for a total of three weeks. The first two days were devoted to equipment familiarization. At the

start of testing (usually Wednesday afternoon of the first week), all of the subjects had reached a minimum level of proficiency. They all improved as they gained experience. Most of the night testing was conducted during the third week after they had improved over their initial day trials. Figures 13 and 14 show plots of several subjects' times to complete a trial as a function of the number of iterations each had performed. Note that the mean time for the day trials was 15.92 minutes, while the mean time for the night trials, which occurred after the day trials, was 14.07 minutes. If the day data, which contains a known bias (inexperience) were summarized and compared to the night data, a false (and generally unbelievable) picture would be developed. To present a more accurate estimate of "reasonably trained" MHE operators during daylight conditions, and to remove the worst effects of the "learning curve" phenomenon, the highest 20% of the daylight performance times were removed from the sample. This caused a 10-15% reduction in the mean times and, as might be expected, a 20-30% reduction in the sample standard deviation.

Night Data

Although all of the test subjects were more experienced when the night testing began, they were NOT experienced at night operations. Therefore, the night data were reviewed to try to insure no obvious bias existed. Each sample contained one very high data point that had been caused by inexperience at night. Therefore, it was decided that it would be more valid to discard the single highest data point from the sample for each cycle-phase-lighting system combination.

These, then, are the data that went into the summary found in Table 1. Figures 15 through 31 contain a histogram with the "best fit" of a truncated normal curve fitted to the histogram.

PHOTOMETER MEASUREMENTS

In order to quantify the differences in emitted light between the standard system and the HELFAST concept, a laboratory quality Pritchard Spectra Photometer, Model 1980, was used (see Figure 32). Measurements were made with a "Cosine-Corrected Integrator Attachment" which measures the total light entering the cone of the lens. The photometer was 30 feet from the forklift. Measurements were made on a moonless night against a background that measured 1.6×10^{-7} foot candles.

Table 2 summarizes the results. (Values are in foot-candles.)

Figure 13. Test results for selected subjects as a function of the number of iterations, day.

25
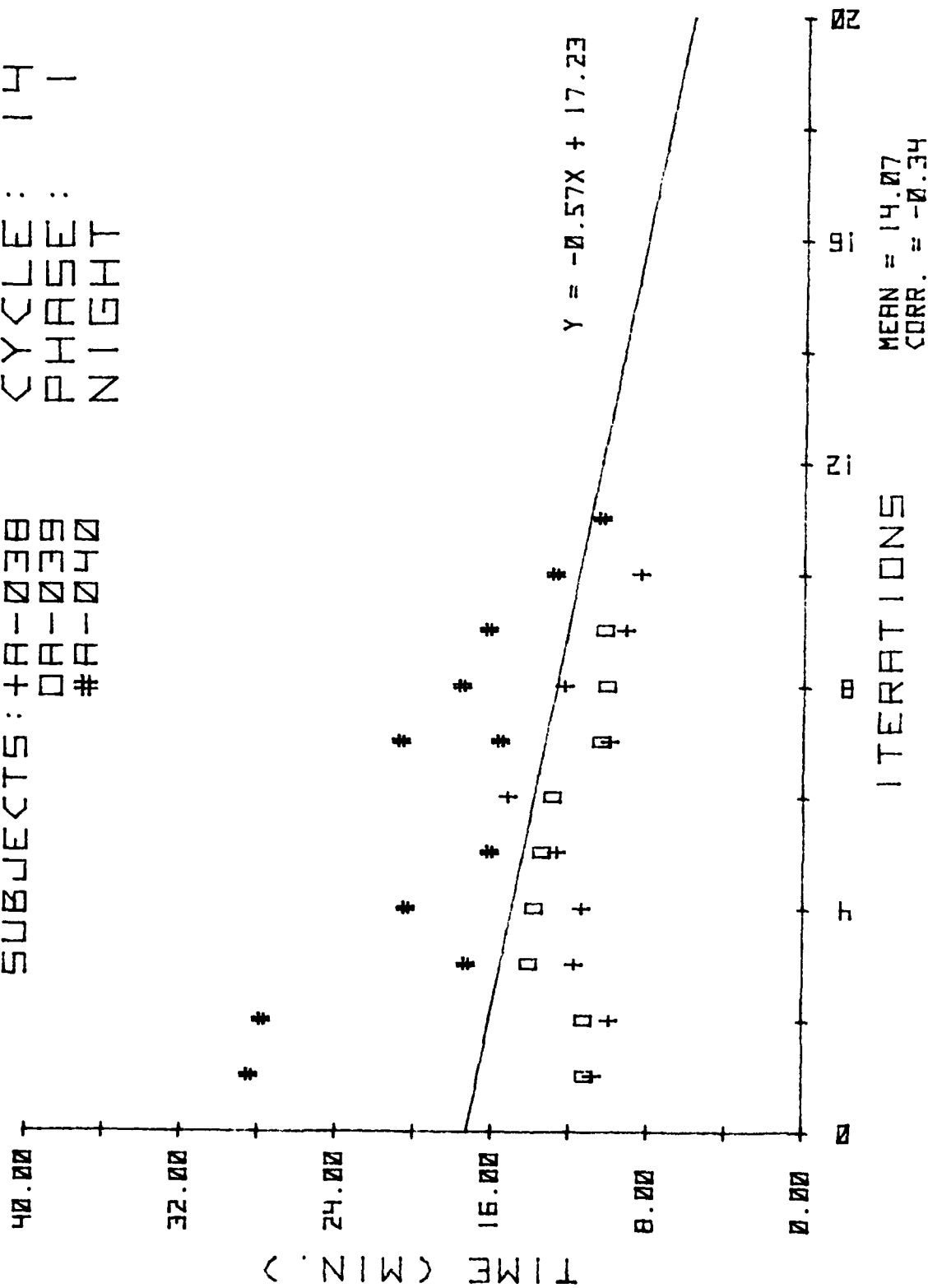
Figure 14. Test results for selected subjects as a function of the number of iterations, night.

TABLE 1

Operational Test Data Summary

CYCLE	PHASE	LIGHTS	N	MEAN TIME (MIN)	STAND DEV (MIN)
14	1	DAY	41	14.16	2.89
14	1	NO. 2	14	12.49	2.59
14	1	NO. 4	14	13.65	3.83
14	2	DAY	40	14.18	2.75
14	2	NO. 2	14	12.98	2.68
14	2	NO. 4	14	13.83	2.20
19	1	DAY	56	7.58	1.20
19	1	NO. 2	15	8.01	1.92
19	1	NO. 4	13	8.30	1.56
19	2	DAY	50	9.31	2.11
19	2	NO. 2	15	8.65	2.28
19	2	NO. 4	14	9.25	2.59
32	1	DAY	36	5.21	0.90
32	1	NO. 2	11	5.77	1.24
32	1	NO. 4	11	6.33	0.91
32	2	DAY	NOT TESTED		
32	2	NO. 2	11	7.00	1.10
32	2	NO. 4	12	7.85	1.06
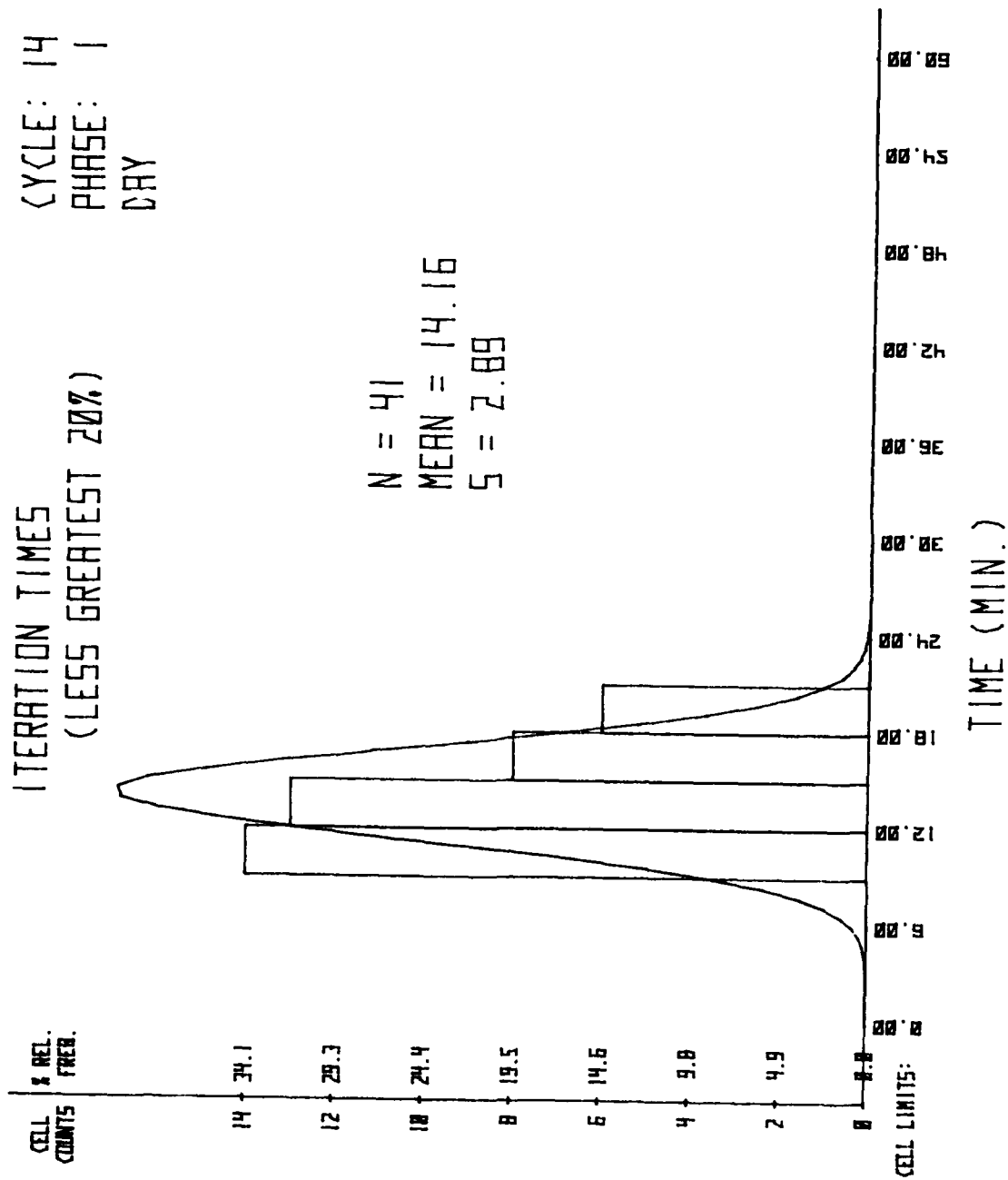
Figure 15. Histogram and curve of cycle 14, Phase 1, day data.

ITERATION TIMES
(LESS SINGLE HIGHEST DATA POINT)

CYCLE: 14
PHASE: 1
NIGHT 02

N = 14
MEAN = 12.49
S = 2.59

Figure 16. Histogram and curve of cycle 14, Phase 1, No2 data.

ITERATION TIMES
(LESS SINGLE GREATEST DATA POINT)

CYCLE: 14
PHASE: 1
NIGHT 04

N = 14
MEAN = 13.65
S = 3.83

CELL COUNTS	% REL. FREQ.
6	42.9
5	35.7
4	28.6
3	21.4
2	14.3
1	7.1
0	0.0

CELL LIMITS:

TIME (MIN.)

0.00 6.00 12.00 18.00 24.00 30.00 36.00 42.00 48.00 54.00 60.00

Figure 17. Histogram and curve of cycle 14, Phase 1, No4 data.

30
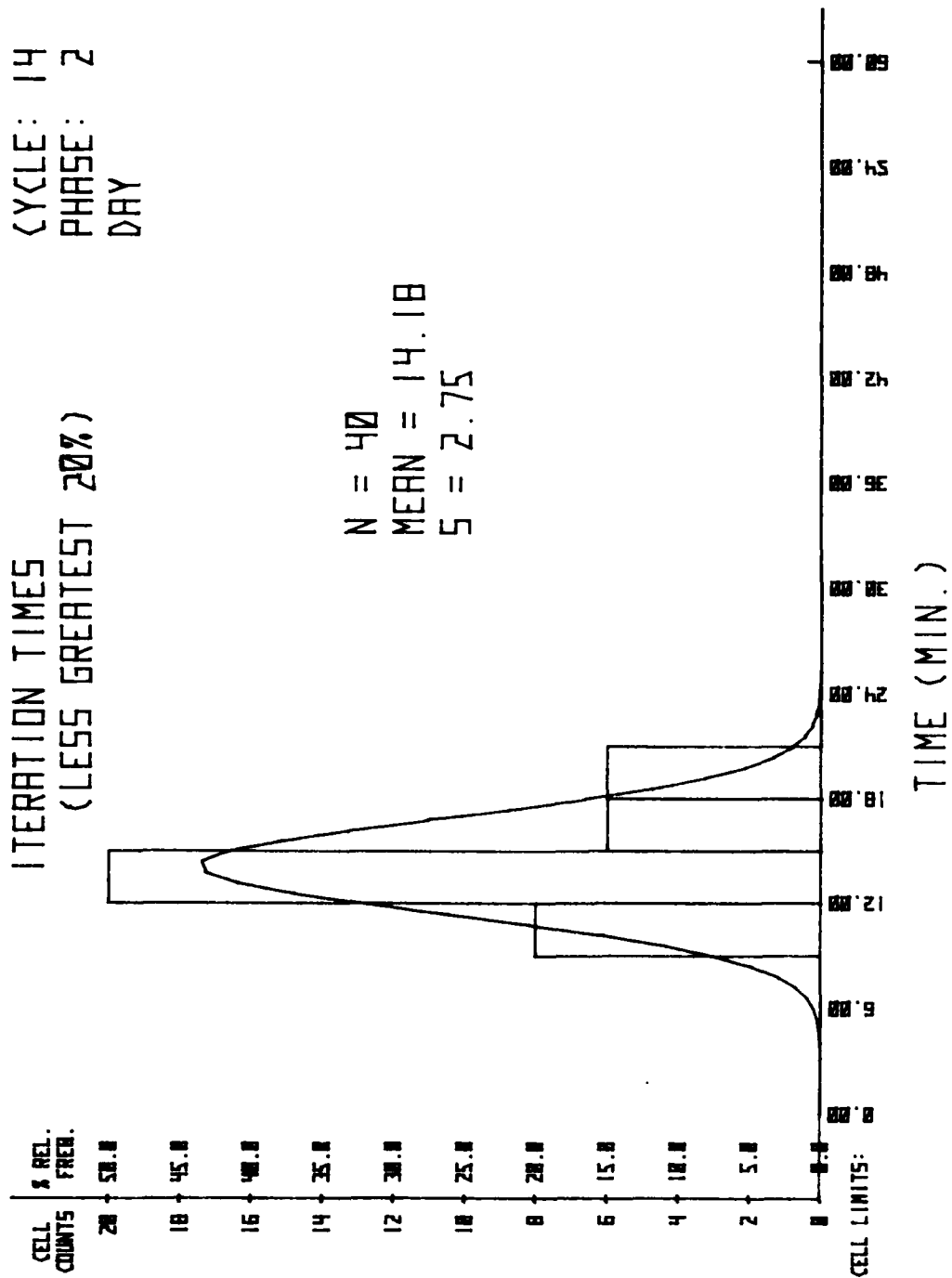
Figure 18. Histogram and curve of cycle 14, Phase 2, day data.

ITERATION TIMES
(LESS SINGLE HIGHEST DATA POINT)

CYCLE: 14
PHASE: 2
NIGHT 02

N = 14
MEAN = 12.98
S = 2.68

TIME (MIN.)

CELL COUNTS	% REL. FREQ.
7	50.0
6	42.9
5	35.7
4	28.6
3	21.4
2	14.3
1	7.1
0	0.0

CELL LIMITS:

0.00 6.00 12.00 18.00 24.00 30.00 36.00 42.00 48.00 54.00 60.00
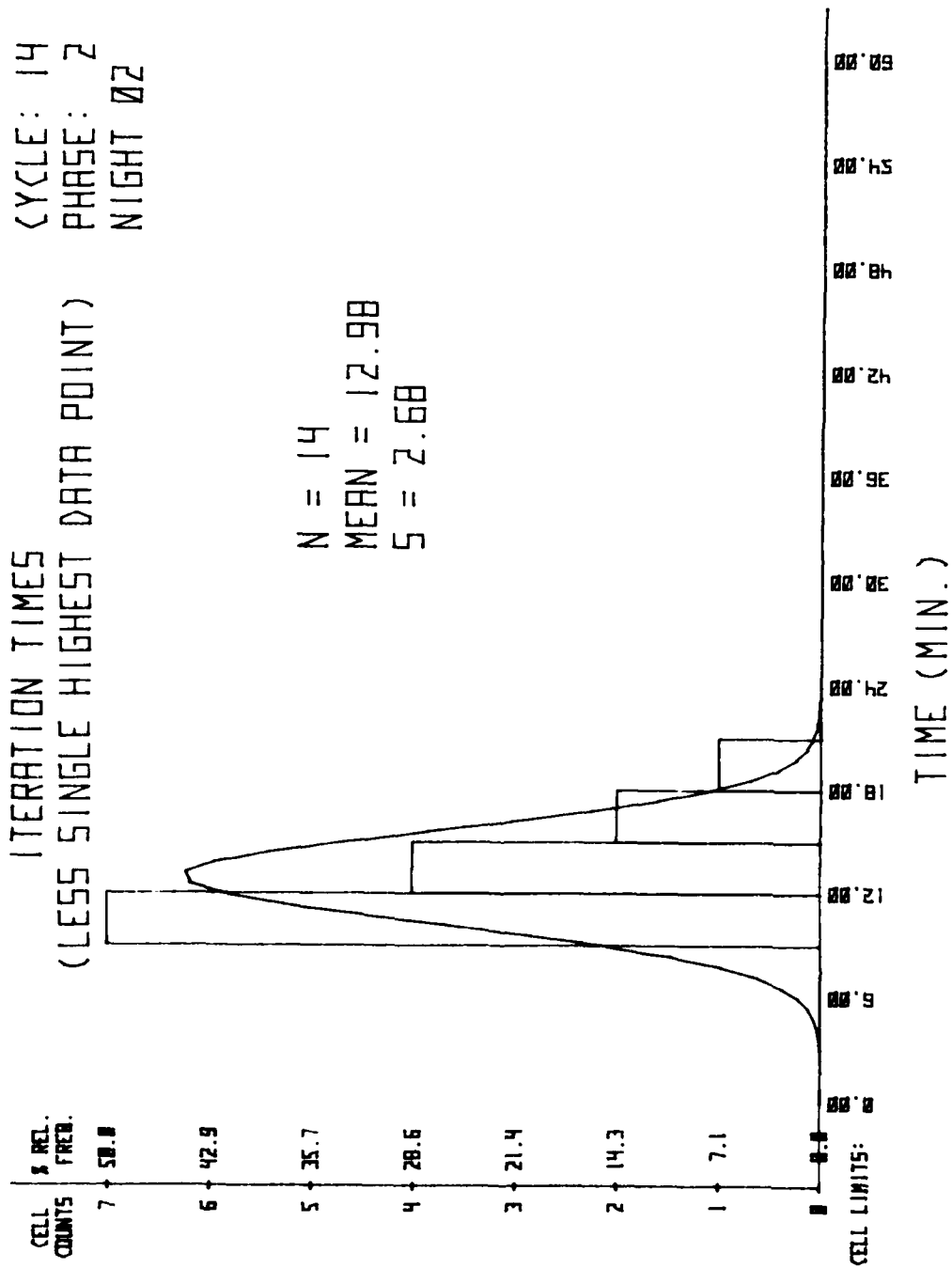
Figure. 19. Histogram and curve of cycle 14, Phase 2, No2 data.
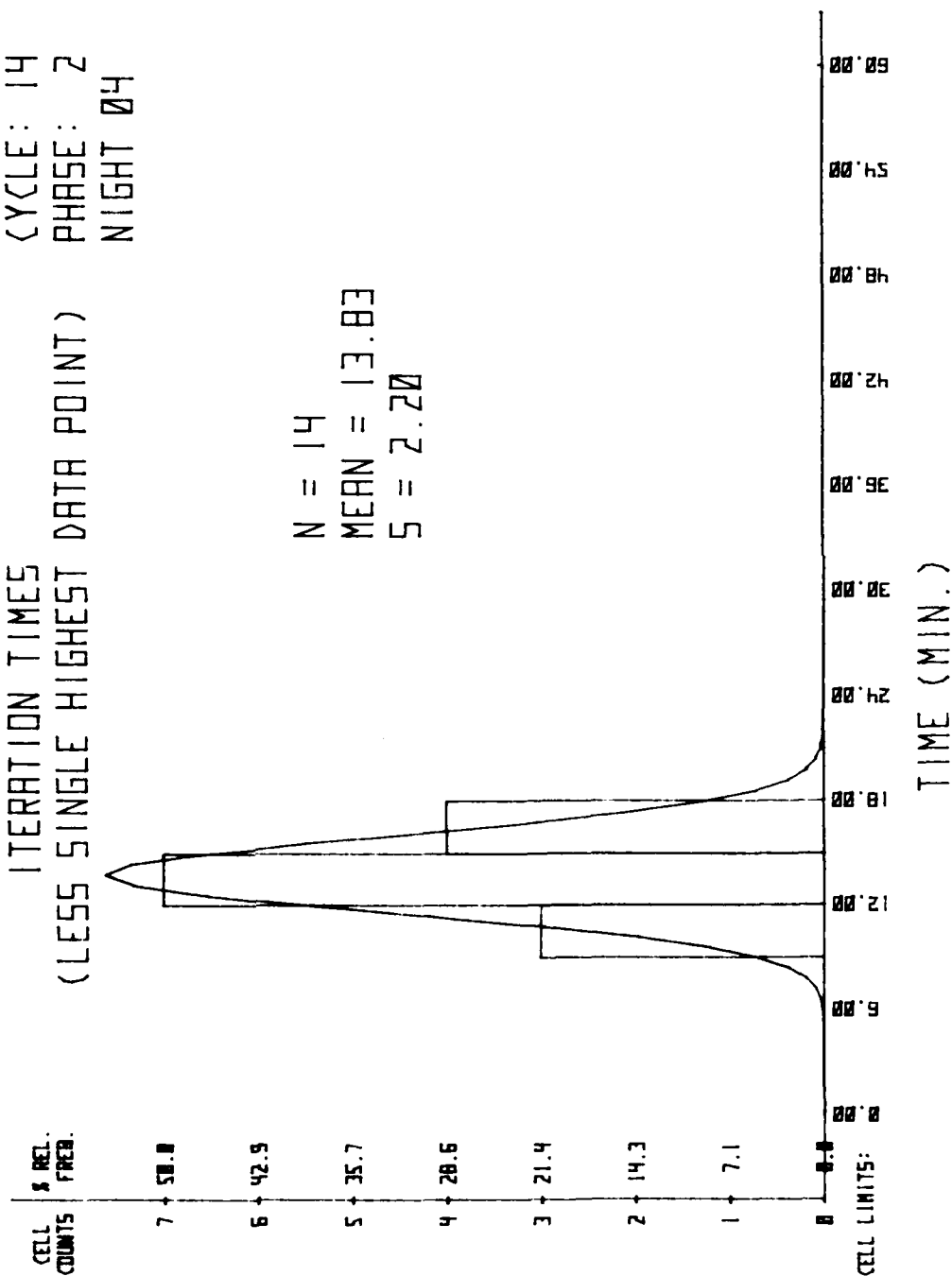
Figure 20. Histogram and curve of cycle 14, Phase 2, No4 data.

Figure 21. Histogram and curve of cycle 19, Phase 1, day data.
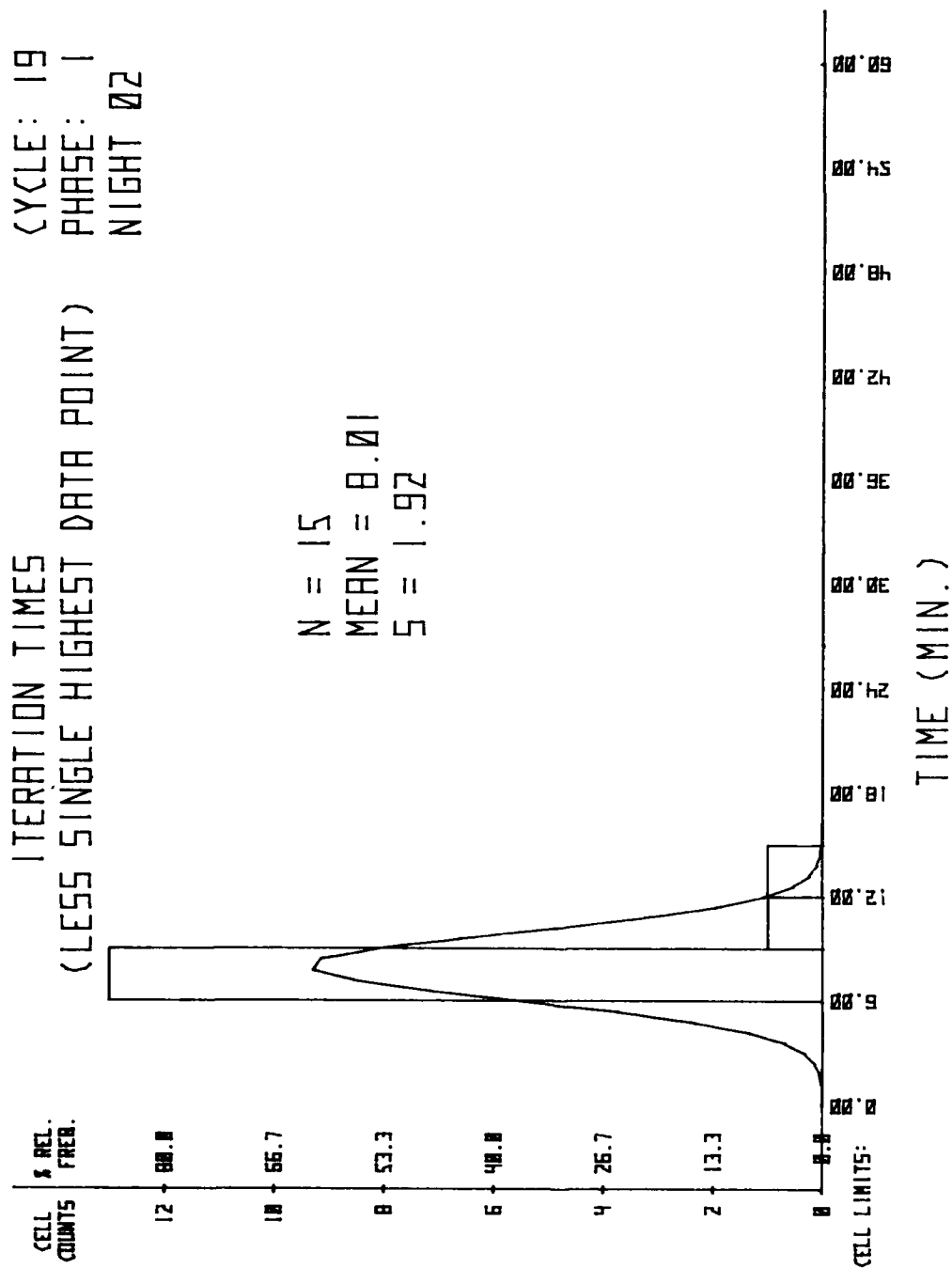
Figure 22. Histogram and curve of cycle 19, Phase 1, No2 data.
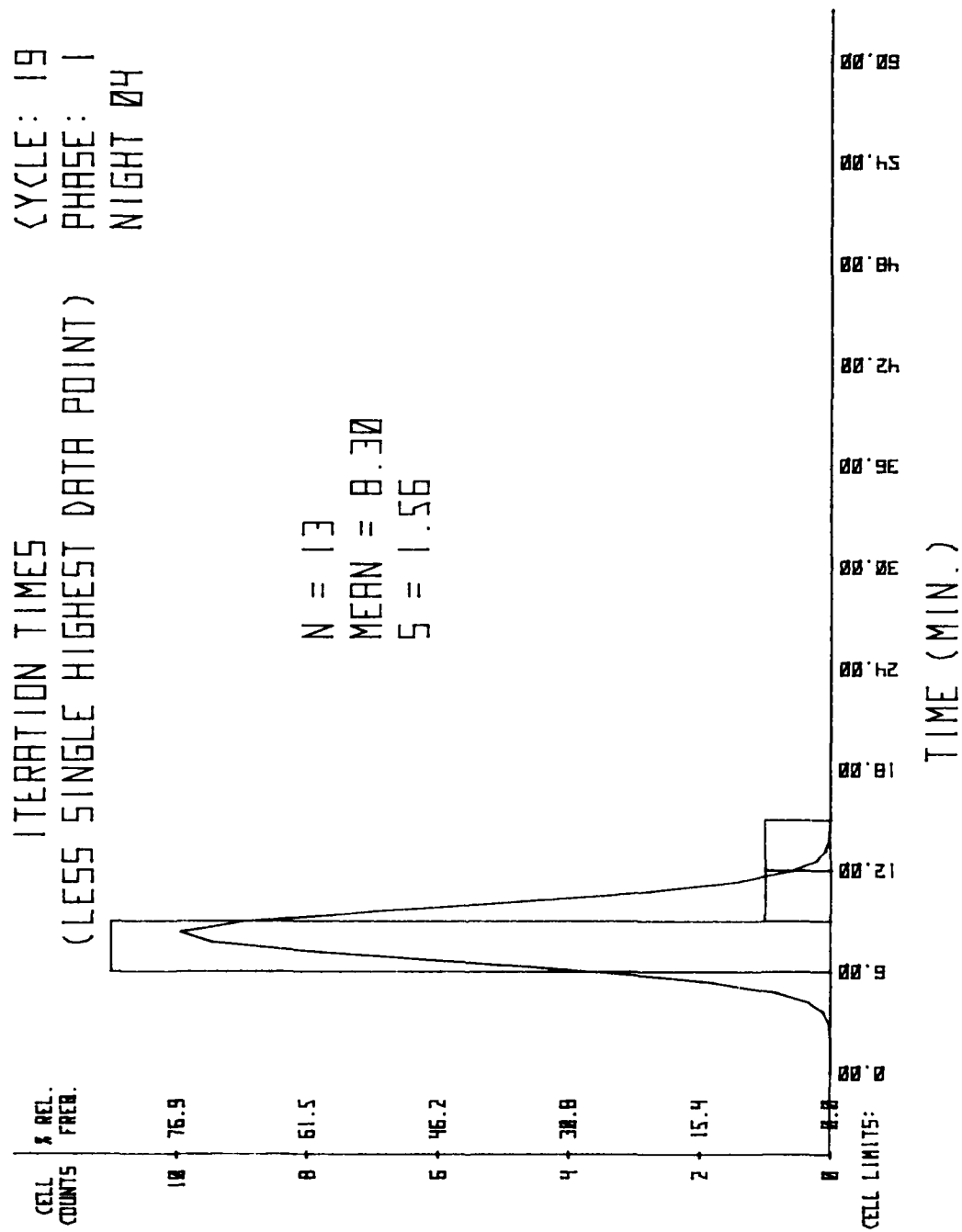
Figure 23. Histogram and curve of cycle 19, Phase 1, No4 data.
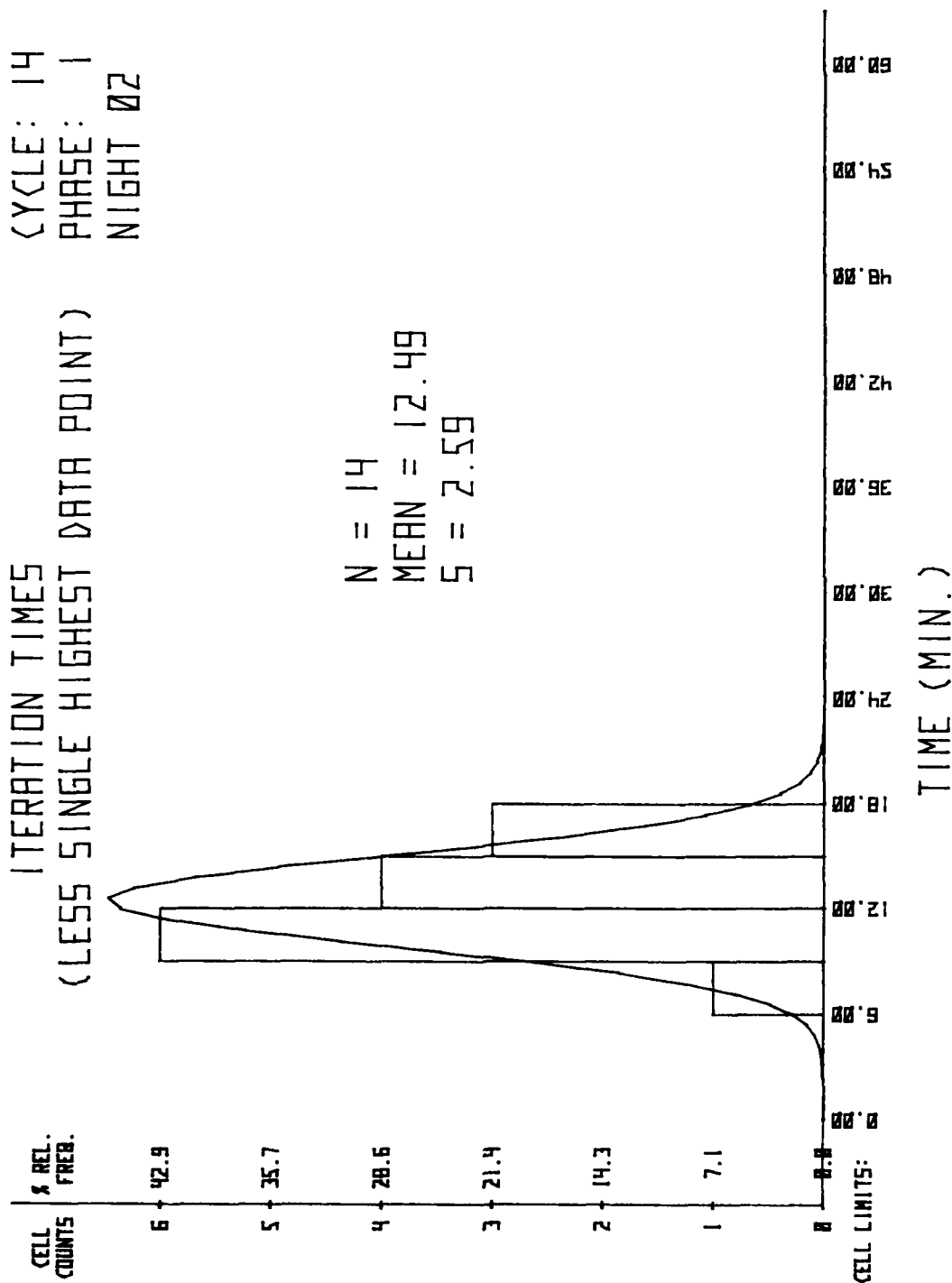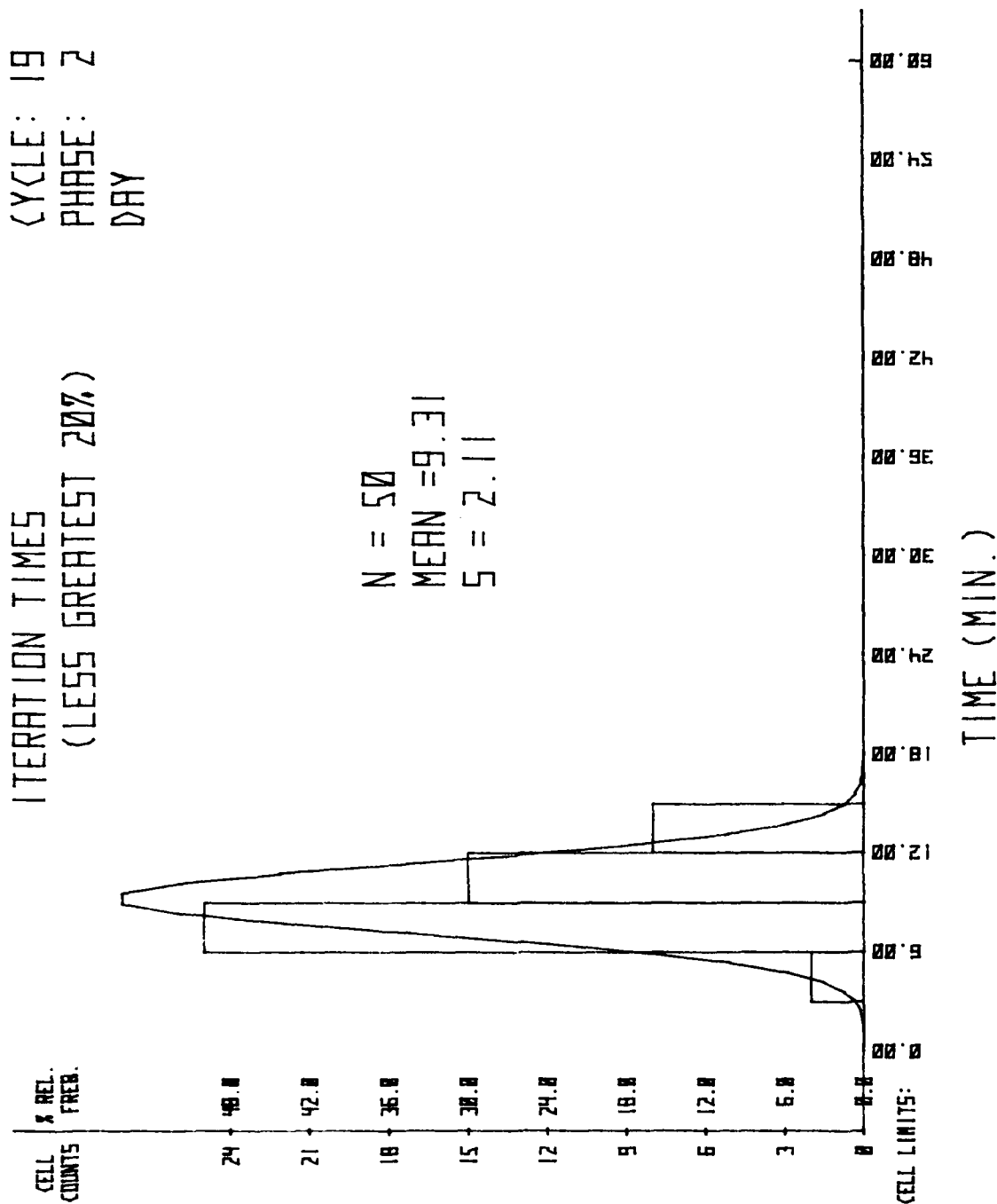
Figure 24. Histogram and curve of cycle 19, Phase 2, day data.

Figure 25. Histogram and curve of cycle 19, Phase 2, No2 data.

ITERATION TIMES
(LESS SINGLE HIGHEST DATA POINT)

CYCLE: 19
PHASE: 2
NIGHT 04

N = 14
MEAN = 9.25
S = 2.59

CELL
COUNTS | % REL.
FREQ.

8 + 57.1
7 + 50.0
6 + 42.9
5 + 35.7
4 + 28.6
3 + 21.4
2 + 14.3
1 + 7.1
0 | 0.0

CELL LIMITS:

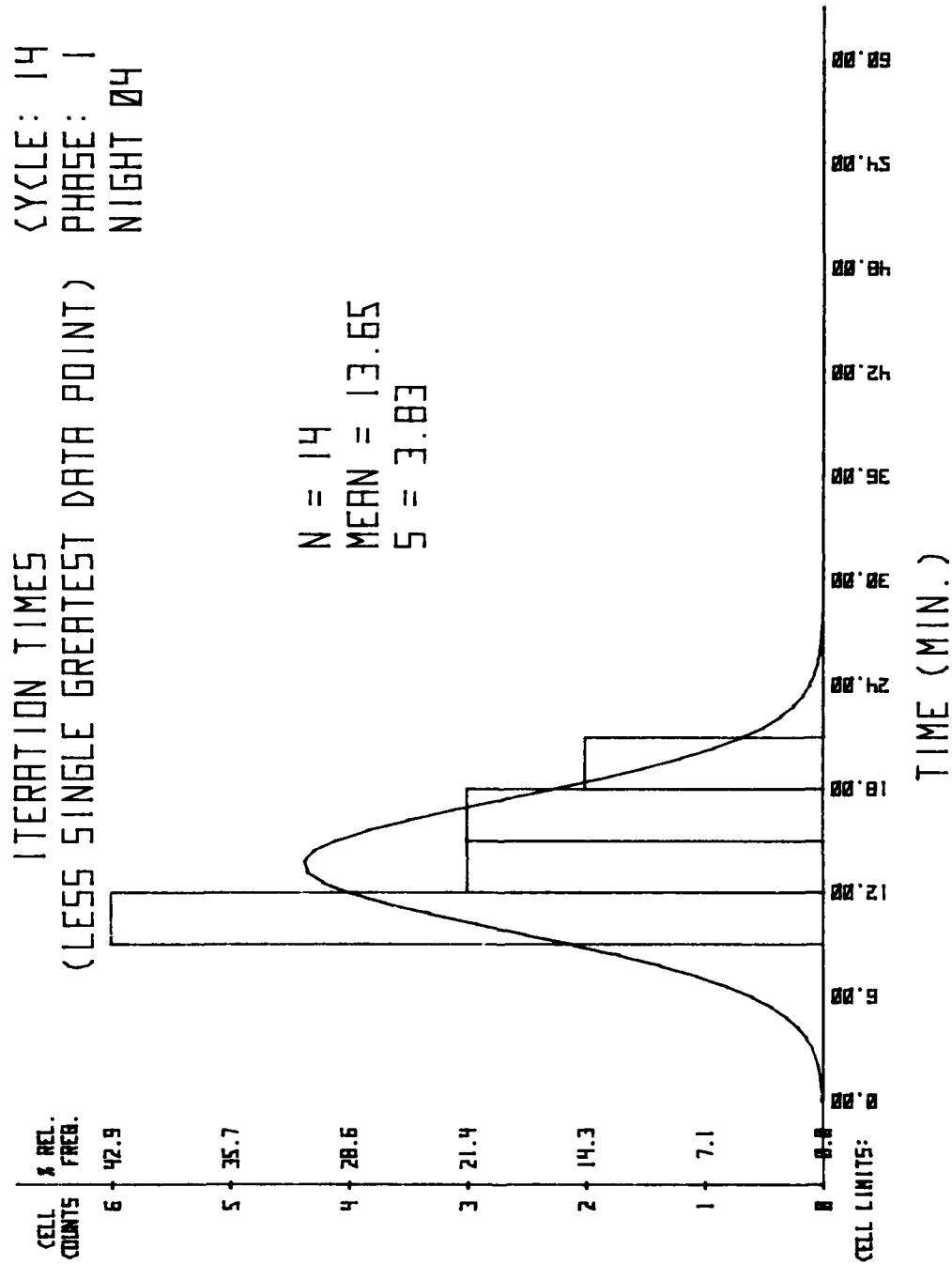0.00   6.00   12.00   18.00   24.00   30.00   36.00   42.00   48.00   54.00   60.00

TIME (MIN.)
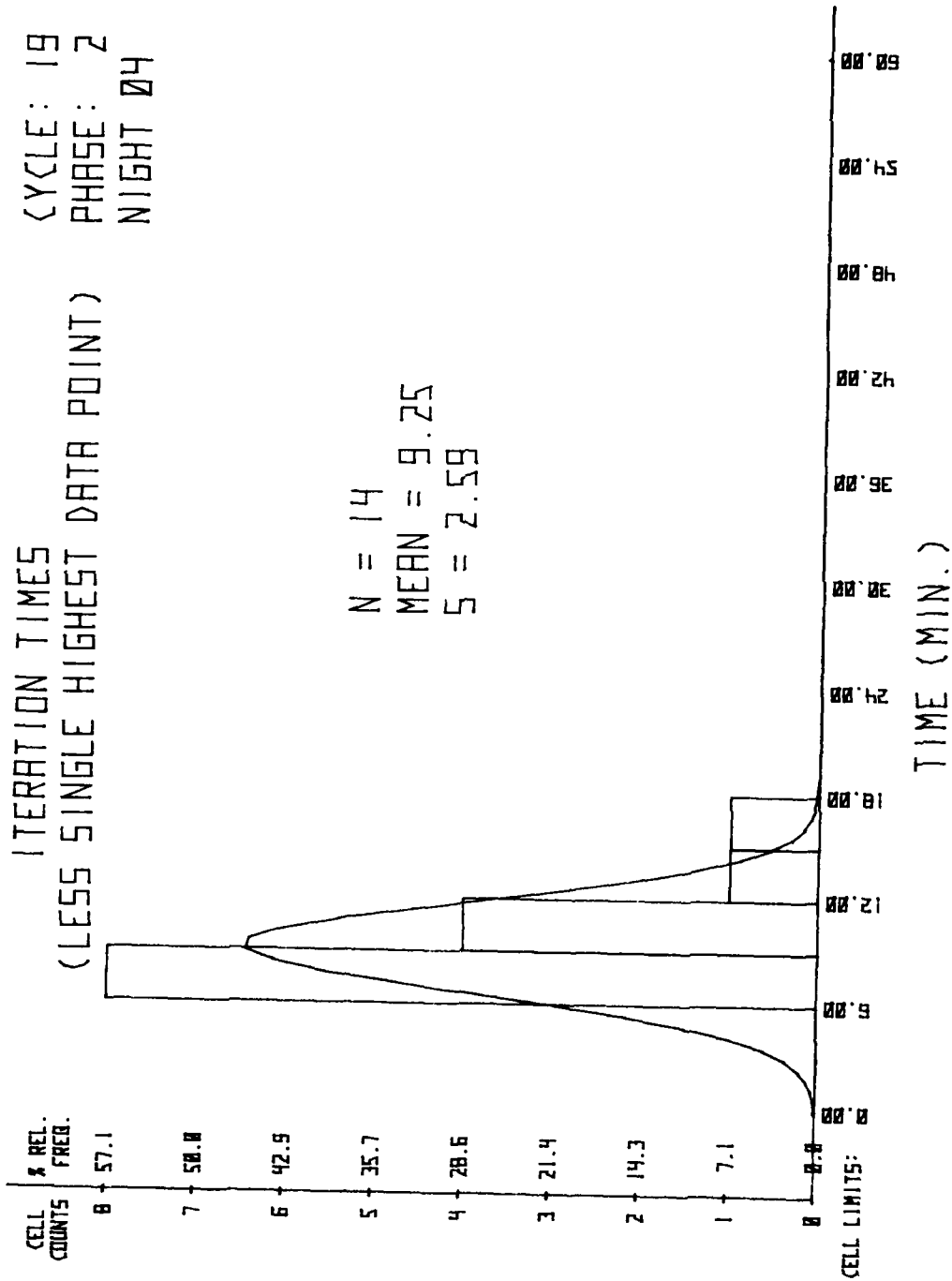
Figure 26. Histogram and curve of cycle 19, Phase 2, No4 data.

Figure 27. Histogram and curve of cycle 32, Phase 1, day data.

Figure 28. Histogram and curve of cycle 32, Phase 1, No2 data.

ITERATION TIMES
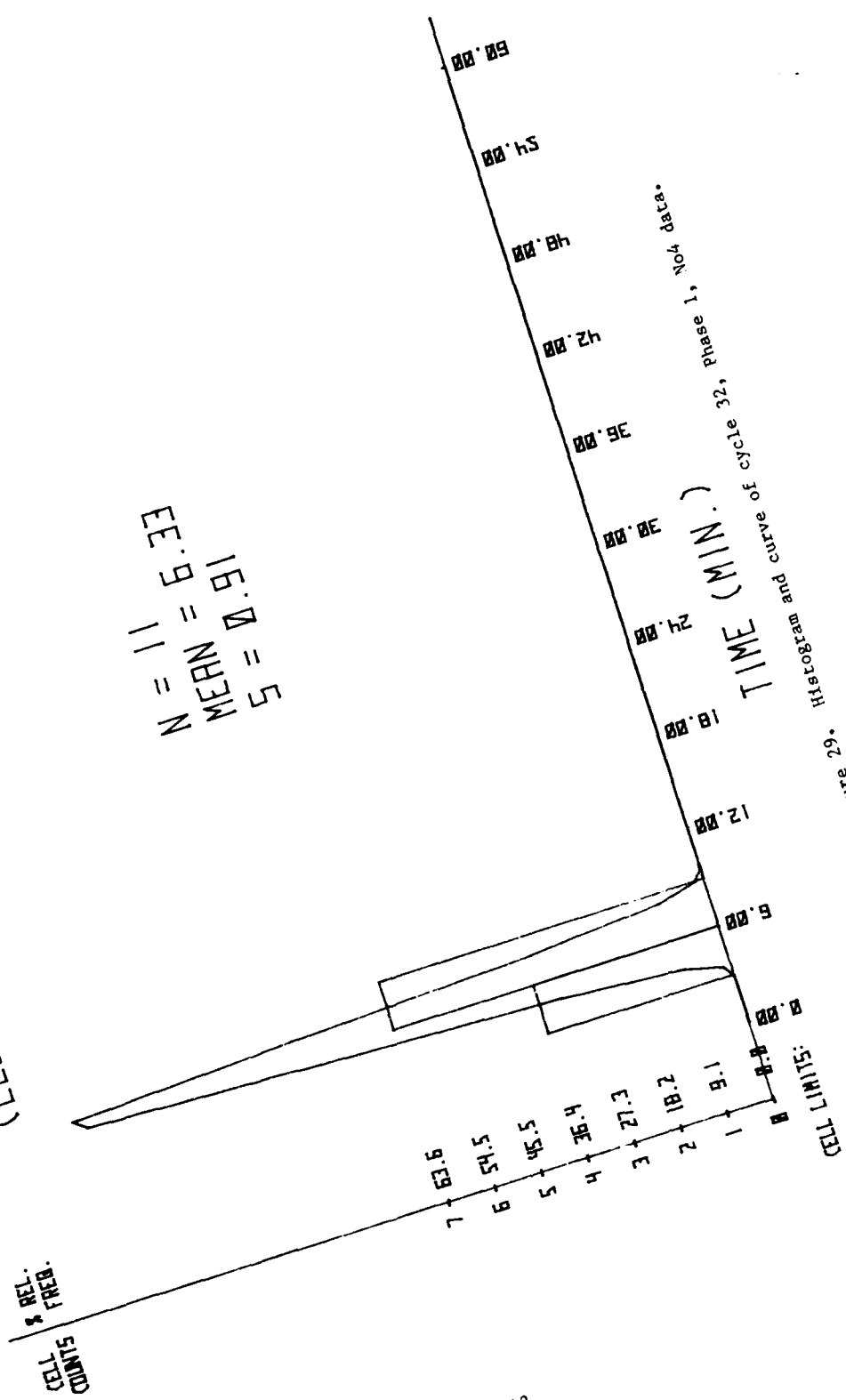
(LESS SINGLE HIGHEST DATA POINT)

N = 11
MEAN = 6.33
S = 0.91

TIME (MIN.)

Figure 29. Histogram and curve of cycle 32, Phase 1, No.4 data.

CELL LIMITS:

CELL COUNTS	% REL. FREQ.
7	63.6
6	54.5
5	45.5
4	36.4
3	27.3
2	18.2
1	9.1
0	0.0

42

ITERATION TIMES
(LESS SINGLE HIGHEST DATA POINT)

CYCLE: 32
PHASE: 1
NIGHT 04

N = 11
MEAN = 6.33
S = 0.91

Figure 29. Histogram and curve of cycle 32, Phase 1, No4 data.
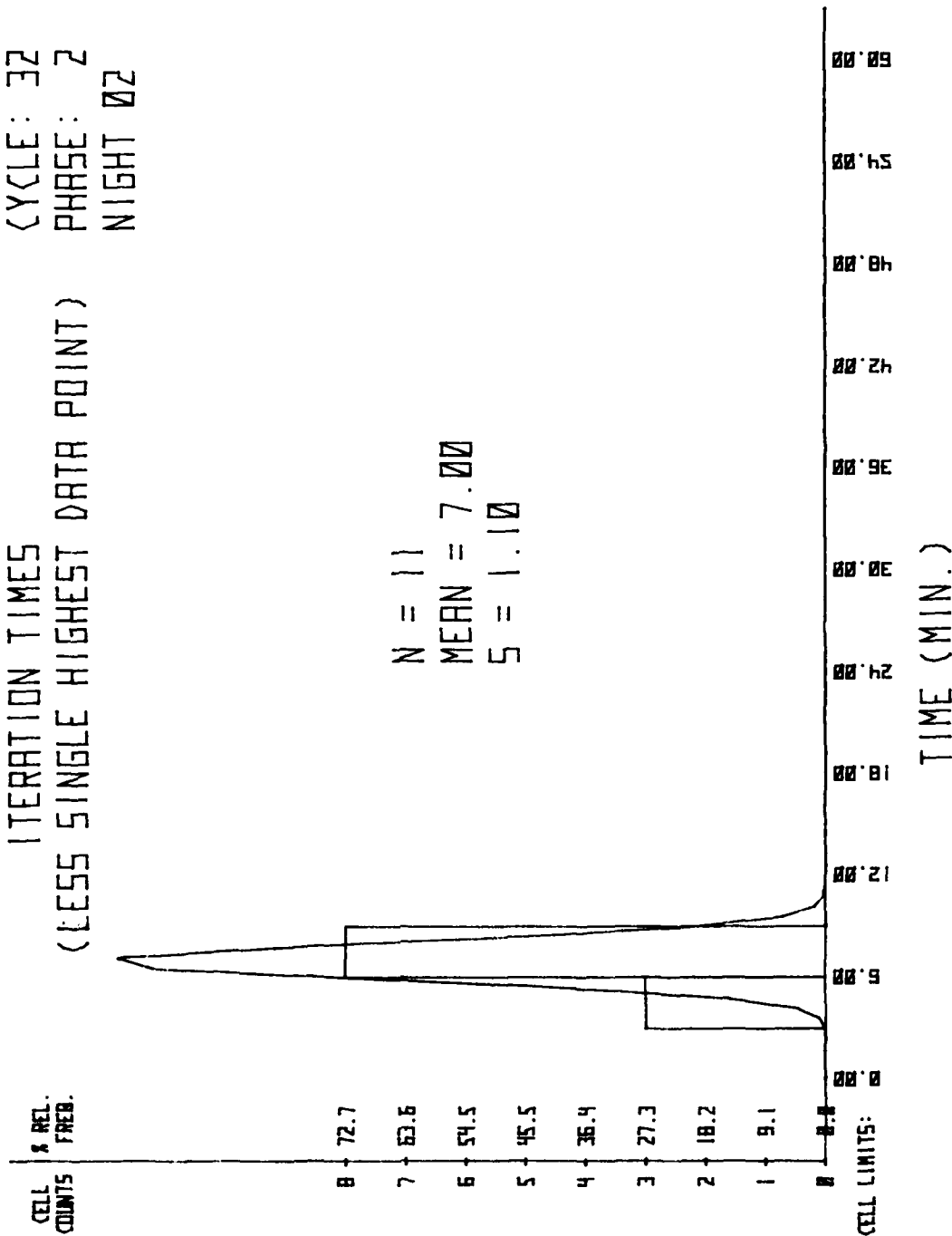
Figure 30. Histogram and curve of cycle 32, Phase 2, No2 data.

ITERATION TIMES
(LESS SINGLE HIGHEST DATA POINT)

CYCLE: 32
PHASE: 2
NIGHT 04

N = 12
MEAN = 7.85
S = 1.06

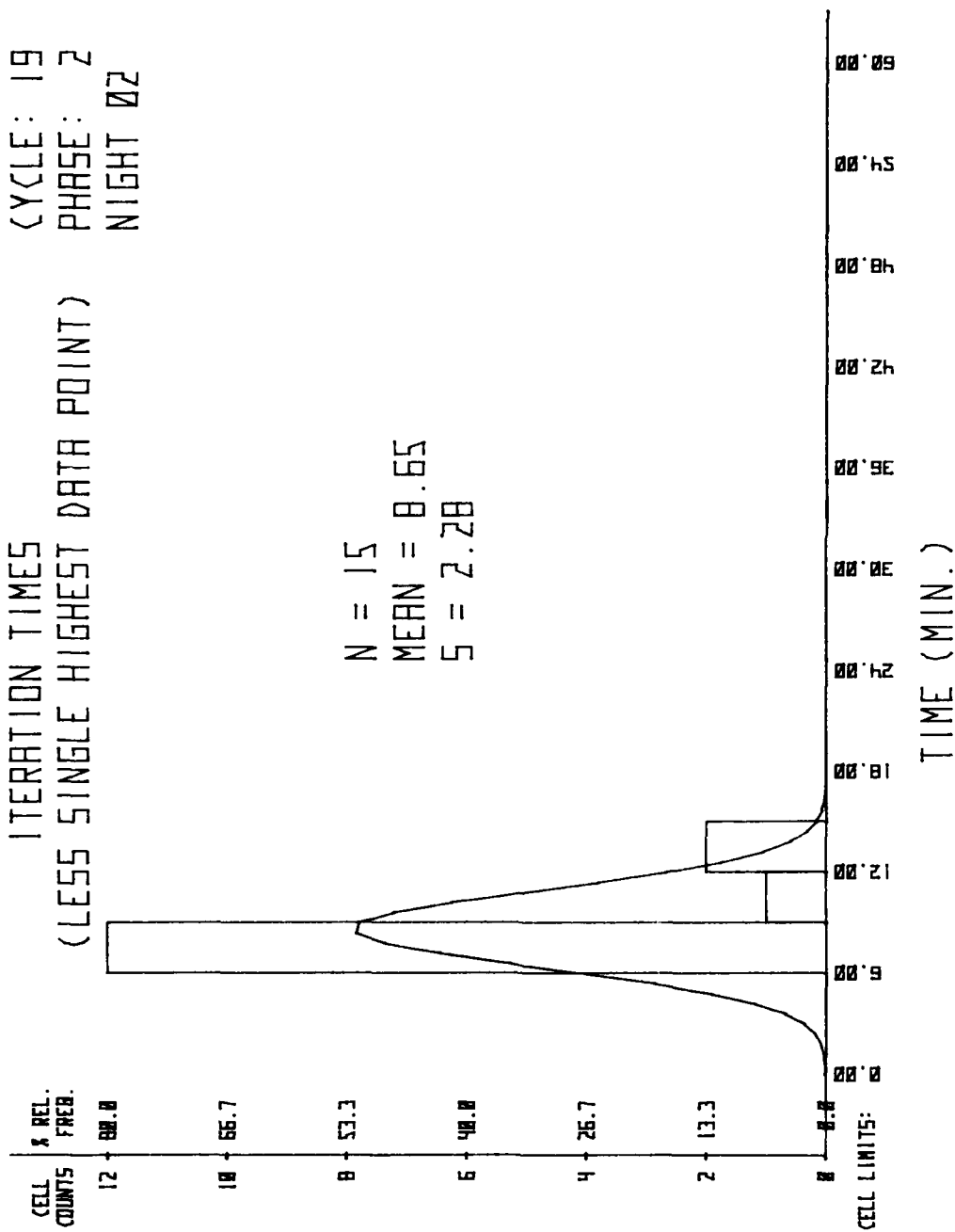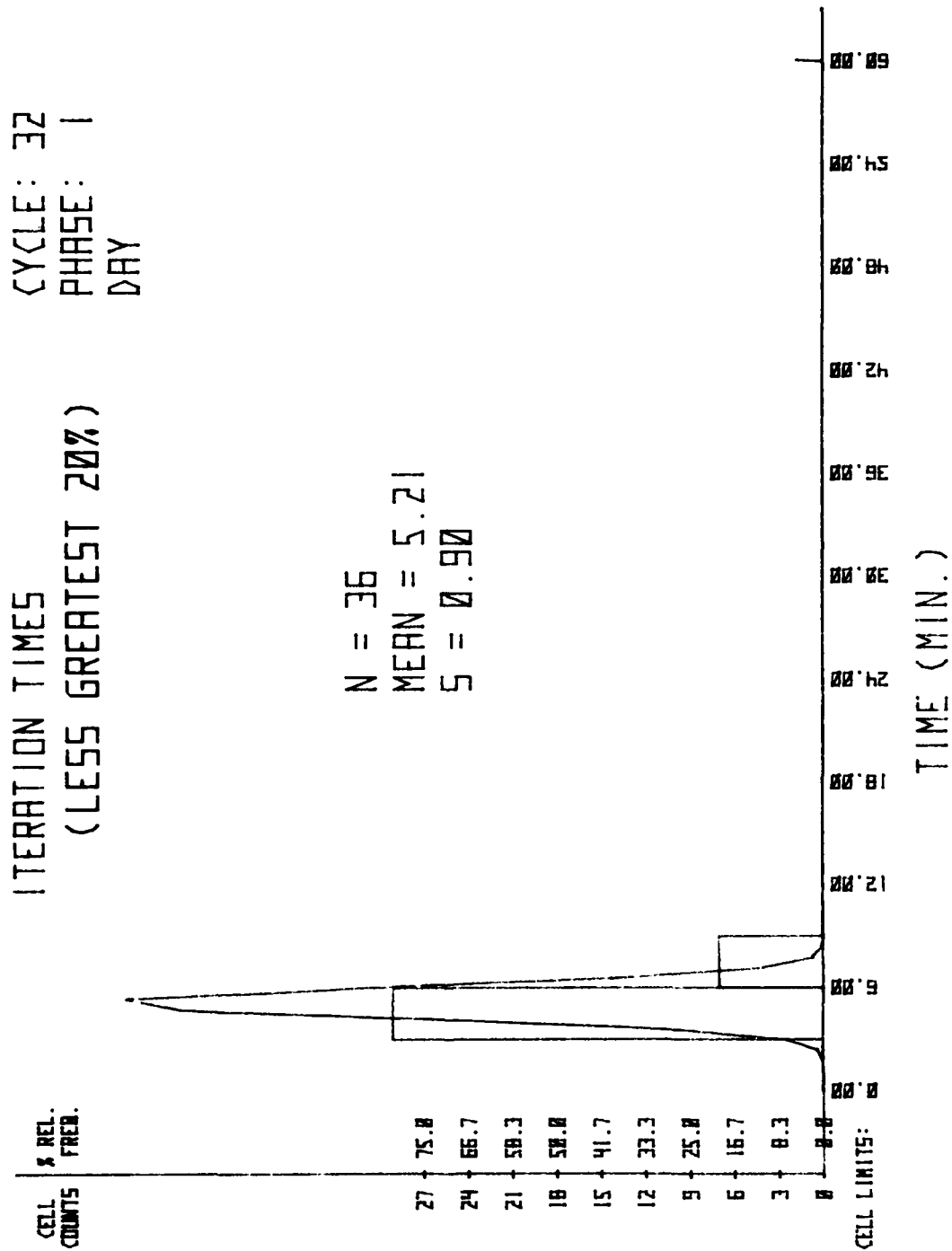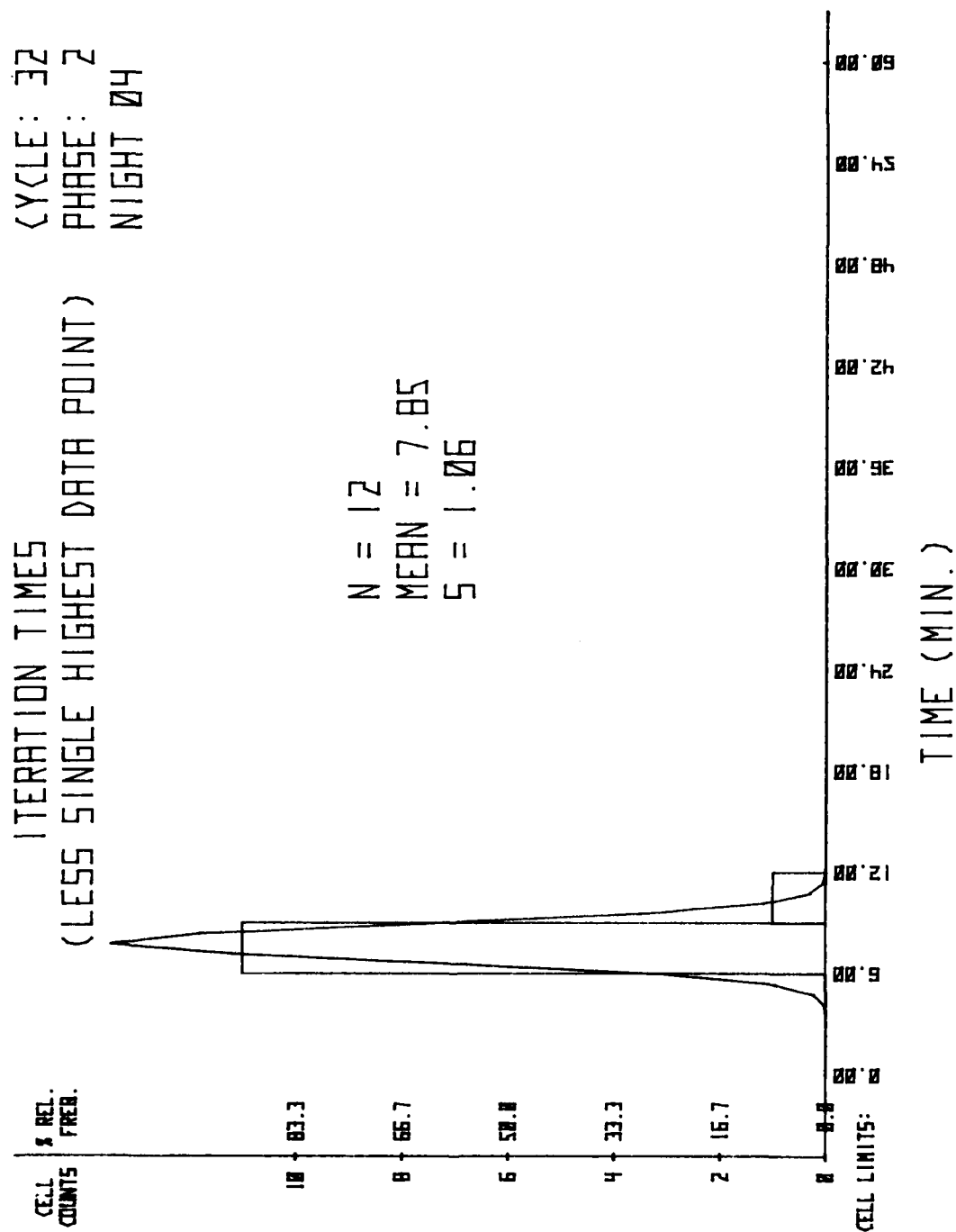Figure 31. Histogram and curve of cycle 32, Phase 2, No4 data.

44
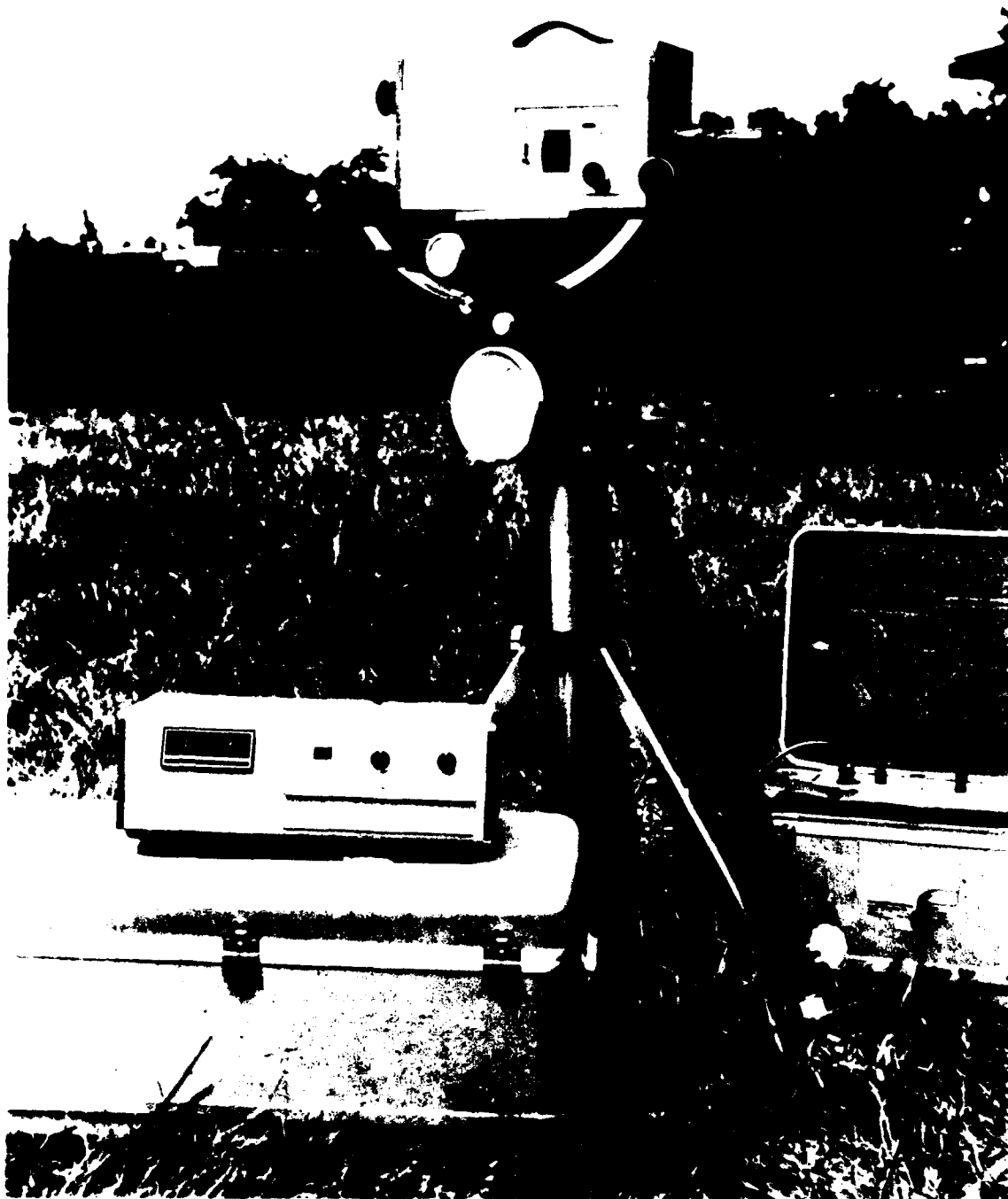
Figure 32. Pritchard Photometer Model 1980.

TABLE 2

Results of Photometer Measurements
(Foot-Candles)

	6,000-lb RTFL	10,000-lb RTFL
Standard Head and Floodlights	$13.30 \times 10^{\circ}$	$10.50 \times 10^{\circ}$
HELFAST Lights	7.0×10^{-3}	9.50×10^{-3}

AERIAL DETECTION TEST

Although the photometer measurements give the differences measured in a static, ground mode, with great accuracy and precision, one cannot equate these differences to the differences in aerial detectability when the fork-lifts are operating in a dynamic mode. Therefore, to establish that there was at least a difference in aerial detectability, a night flight was made using a UH-1 helicopter and four observers. (The test plan is included as Appendix A.)

During this test, three of the four observers were experienced pilots (one Army, one Air Force and one civilian) with a total of 70 years of flying experience. The fourth observer was not a pilot.

Test Bias

Although the test site itself is bordered by trees, isolated and dark, it is surrounded on three sides by Edgewood Arsenal and the town of Edgewood. From the air, it is one of many dark fields surrounded by lights. In order for the observers to pick out the correct test site, a high-powered beacon and a strobe light were used. Nevertheless, the aircraft had to be within 5 kilometers of the test site before these aides were useful. Therefore, although the standard lights might have been detectable from much longer ranges had the test environment been more realistic, the detection ranges were shortened due to the problem of finding the test site.

TEST RESULTS

See Table 3 below.

46

TABLE 3

Night Aerial Detection Test Results

	Mean Range for Detection (Meters)
Standard Head and Floodlights	3200
HELFAST Lights	1100

SECTION III

DISCUSSION

A review of the operational test data summarized in Table 1 shows that
for the six cycle-phase combinations listed, in three cases using the
HELFAST lights, the mean performance times were better than the time
required to perform the same test during daylight. In the other two cases
that have daylight performance time, the mean times with the HELFAST lights
are within 10% of the daylight times. In the last case (cycle 32, phase 2),
no daylight times were available, but the HELFAST times exceed the times
using the standard lights by 12%. Thus, in five of the six cases tested,
the HELFAST concept met or exceeded the stated goal.

Photometer measurements show that, when measured in the horizontal
plane, the light emitted by the HELFAST concept lights was on the order of
one one-thousandth of the light emitted by the standard lights. (Note: This
is NOT to imply that aerial detection is reduced by a factor of one thou-
sand.)

If anything, the aerial detection test was biased to make the standard
lights seem less detectable than they actually may be in a combat environ-
ment. However, even with this bias, the aircraft had to close to one-third
of the range for the HELFAST lights to be detected. At 90 knots, this
allowed the observers about 45 seconds of "search time." However, in an
aircraft going 450 knots, this search time would be reduced to about 9
seconds and in less than an additional 5 seconds, the aircraft would
overfly the target. One can only speculate as to what this would do to the
probability of detection.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The HELFAST test program examined a wide variety of night lighting options during the preliminary testing and rationally chose one concept for further testing.

2. The operational testing proved conclusively that the HELFAST concept was adequate for night operations with forklifts.

3. Photometric measurements show that the emitted light is reduced by a factor of one thousand.

4. Aerial detection tests show that an aircraft must close significantly for observers to be able to detect forklifts operating with the HELFAST light concept.

5. All test results considered show that the constrained, soft white light concept developed by the HELFAST team allow the operators to perform their mission and significantly reduce the visual signature when viewed from the air.

RECOMMENDATIONS

1. That a fully engineered alternate night lighting system, following the concepts of the HELFAST system, be installed on US Army forklifts.

2. That consideration be given to adopting this same concept to other tactical vehicles that must operate forward of the light line such as signal equipment, engineer construction vehicles, other logistical vehicles, etc.

APPENDIX A

NIGHT AERIAL DETECTION TEST PLAN

HELFAST NIGHT LIGHTING DETECTION TEST

1. Objectives: To quantify the relative differences in detectability from a helicopter of the standard head and floodlights mounted on the 6,000- and 10,000-lb rough terrain forklifts and the reduced, constrained lighting concept developed by the HELFAST team, when the forklifts are performing quasi-operational missions.

2. Variables:

   a. Controlled:

      (1) Location of forklifts.

      (2) Lighting system.

      (3) Aircraft altitude.

      (4) Aircraft direction of flight.

   b. Uncontrolled:

      Winds aloft.

   c. Test Variables:

      (1) Range from center of test site to detection.

      (2) Correctness of observers in detecting the location (quadrant) of forklifts.

   d. Constants:

      (1) Weather.

      (2) Atmospherics.

      (3) Ambient lights.

      (4) Observers.

3. Ground Operations:

   a. Personnel:

      (1) Ground Controller (Iiams; Berstein).

      (2) Two forklift drivers (6K - Winters; 10K - Mackey).

      (3) Two RTFL radio operators (6K - Kimball; 10K - Spencer).

b. Equipment:

   (1) 6,000-lb RTFL.

   (2) 10,000-lb RTFL.

   (3) Strobe light.

   (4) Railroad flares.

   (5) Ammunition pallets.

   (6) Light sticks.

4. Aircraft Operations:
   a. Personnel:

   (1) Controller: Davall.

   (2) Observers: Barnes, Foster, Waugh.

   (3) Pilots: Yensan, Garrett.

   b. Equipment:

   (1) Stopwatches.

   (2) Clipboards and scoresheets.

5. Communications:

   a. Normal aircraft operational nets.

   b. Air-to-ground control net.

   c. Ground control to forklift nets.

6. Test Methodology:

   a. General: The test site will be divided into quadrants numbered clockwise from North. Quadrant divisions will be marked with railroad flares. The center of sector will be marked with a strobe light. For each of the eight tests, the quadrant location and lighting system for each forklift will be designated but unknown to the observers. While the aircraft flys away from the test site, the forklifts will move to the approximate center of their designated quadrant for the next test, face the direction of approach of the aircraft, and turn on the appropriate lighting system. At the start of the test, the forklifts will move forward about 30', pick up an ammunition pallet, back up and turn 90°, move forward 30', put the pallet down, back up, stop, then move forward, pick up the pallet and repeat the exercise until told that test is over. Thus, the forklifts

will be performing quasi-operational missions and the lights will be generally pointed in the direction of the approach of the aircraft. Once the aircraft is sufficiently far away (at least 2.5 km at 800' and 6.5 km at 2000') to mask the test site, and all is ready on the ground, the aircraft will turn and fly at the specified altitude, directly at the center of the test site (marked by the strobe light). During this flight in, the observers will try and detect the forklifts. Once detected, the observers will record the quadrant and which lighting system is being used (high or low) and the time the observation is made. The test will terminate when the aircraft passes over the strobe light.

b. Trials: Eight trials will be conducted, plus one practice trial.

Four trials will be at a low altitude, 800 feet, and four at a higher altitude of about 2,000 feet. At each altitude the aircraft will make one pass in each of the four cardinal directions.

c. Forklift locations: For each trial, the forklift location and lighting system used have been selected using random numbers. This trial matrix is published separately at the end of this appendix.

d. Scoresheets: Observers will record the results of each trial on the scoresheet shown in Appendix B.

e. Time: At the start of a trial, the aircraft controller will start a timer. When the observers detect a forklift, they will glance at the timer and will enter the time on the scoresheet.

7. Scoring:

a. Test will be scored by converting the time at which a correct detection is made to a distance. Averaging these values will give quantified and comparable detection ranges.

b. The purpose of the test quantify the relative differences between a standard lighting system and a conceptual reduced light system. This test will NOT give any measure of the absolute detectability of either lighting system.

TRIAL MATRIX

(Close Hold – Published Separately)

TRIAL	6K Quad	6K Lights	10K Quad	10K Lights	Aircraft[a] Alt	Aircraft[a] Dir of FLT
1	3	H	1	L	800'	North
2	2	L	3	L	800'	South
3	1	H	2	H	800'	West
4	3	L	1	H	800'	East
5	4	L	2	L	2000'	West
6	1	H	4	H	2000'	East
7	3	H	3	L	2000'	South
8	1	L	4	H	2000'	North

[a]Aircraft altitudes and flight directions are subject to adjustment after dry run.

APPENDIX B

SCORESHEET

SCORESHEET

OBSERVERS NAME _____

AGE _____ DO YOU WEAR GLASSES _____YES _____NO

ARE YOU A PILOT _____YES _____NO

IF YES, HOW MANY YEARS FLYING _____

TYPE AIRCRAFT _____ HELICOPTER _____PROP_____JET

TRIAL	ALT	AIRSPEED	FIRST RTFL			SECOND RTFL		
			QUAD	LIGHTS	TIME	QUAD	LIGHTS	TIME
1								
2								
3								
4								
5								
6								
7								
8								

QUADRANTS

TRAILER

N

60